Science Advisory Panel

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Alaska Department of Environmental Conservation

Commercial Passenger Vessel Environmental Compliance Program

The Impact of Cruise Ship Wastewater Discharge on Alaska Waters

November 2002

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FOREWORD

Alaskans cherish and rely upon our wild resources for nutrition, cultural integrity, livelihoods, recreation, and spiritual wellbeing. Consequently, major sources of waste discharges into Alaska's marine environments must be managed to maintain the integrity of Alaska's coastal and marine environments, and to ensure that marine resources are not compromised.

It is imperative that cruise ship waste discharges be treated and monitored. It is also critical that we evaluate and understand the impacts that cruise ship wastes have or can potentially have on Alaska's waters and marine resources. To that end, the Alaska Cruise Ship Initiative wastewater and solid waste work group -- comprised of industry, state, federal, and public members -- created a Science Advisory Panel to conduct an independent scientific investigation of the impacts on human health and the environment from cruise ship waste discharges.

The Science Advisory Panel members were carefully selected to ensure a range of expertise for a full, thorough, and scientific assessment of impacts from cruise ship wastes in Alaska. The Science Advisory Panel is an independent body whose work and conclusions are not subject to government or industry approval. The Science Advisory Panel's conclusions or recommendations form the scientific underpinnings for agencies and the public to make policy decisions on how best to work with the industry to manage cruise ship wastes.

The following report of the Science Advisory Panel is a major milestone in the understanding of the impacts from cruise ship waste discharges in Alaska. The Alaska Department of Environmental Conservation is very appreciative of the enormous contributions the Science Advisory Panel has made to the state of knowledge regarding cruise ship industry impacts in Alaska. The Panel's work is valuable not only to Alaskans, but also to other coastal states or countries that are looking for guidance regarding cruise ship waste management practices, governmental oversight, and actual or potential impacts on marine environments.

MICHELE BROWN

Commissioner

Alaska Department of Environmental Conservation

November 25, 2002

Alaska Department of Environmental Conservation

Science Advisory Panel

Commercial Passenger Vessel Environmental Compliance Program

The Impact of Cruise Ship Wastewater Discharge on Alaska Waters

Executive Summary

The Science Advisory Panel was assembled in early 2001 to address all aspects of the potential impact of cruise ship wastewater discharge on Alaska marine waters. Panel members are listed beginning on page vii. Using an assessment framework (Figure i, page x), the Panel started with effluent characterization and dispersion modeling and concluded with exposure assessment and recommendations for risk management and additional research. This paper is the result of this evaluation and represents nearly 20 months of research, fieldwork and discussion. Each aspect of the assessment framework is addressed in a separate section. These sections are summarized below[1].

The authors have emphasized that this paper conveys the "state-of-knowledge" as of November 2002. This work is dynamic and should be revised and changed as new information becomes available.

Although small commercial passenger ships represent only about 6% of passenger vessel wastewater discharge in Alaska waters, their effluent often contains high levels of fecal coliform and suspended solids. These vessels are currently allowed to discharge everywhere. The Panel, therefore, recommends that these ships should avoid stationary discharge, particularly in small fjords and embayments where the movement or flux of water is limited.

Research and evaluations to date indicate that state and federal regulations for large cruise ships which set effluent parameters and require wastewater to be discharged while ships are moving (unless these ships meet stringent effluent limits through advanced treatment) appear to effectively limit the impact of discharge on Alaska receiving waters. The Panel recognizes many people feel that "dilution is not the solution to pollution". However, the mitigating effect of the vigorous mixing action of a moving ship, combined with concentration limits for certain wastewater constituents, is quite apparent. Evaluation of impacts should be continued and guidelines for establishing no discharge zones, should the need arise, are presented in Section VII of this paper.

I. Dilution

Through literature review, fieldwork and evaluation of the EPA plume study off Miami (2001), the Panel developed the following formulas for estimating dilution of wastewater discharged by a moving cruise ship:

[1] A brief glossary of common marine discharge terms used in this section and elsewhere is provided in Appendix 10.

Large Cruise Ship

Dilution factor = 4 x (ship width x ship draft x ship speed)/(volume discharge rate)

=4x (_____m x _____m x _____m sec^{-1})/(_____m^3sec^{-1})

For a typical large cruise ship moving at a minimum speed of 6 knots and discharging wastewater at 200m^3/hr the dilution factor is 50,000.

Small Cruise Ship

Dilution factor = 3 x (ship width x ship draft x ship speed)/(volume discharge rate)

= 3x (_____m x _____m x _____m sec^{-1})/(_____m^3sec^{-1})

Far field dispersion processes assure that additional dilution will occur before any mixture of effluent and water approaches a shore. Under the least favorable conditions, the additional mixing factor will be 1:100 by the time the mixed water reaches a shoreline one mile from the ship's trackline, thus diluting the effluent of a large vessel discharging at 200 m^3 /hr at 6 knots by a factor of 5,000,000 or 50,000 x 100.

II. Sampling

The Panel and ADEC reviewed and summarized all available wastewater sample and analysis data to arrive at the following conclusions:

Obtaining vessel samples that are consistently representative of a discharge (particularly graywater) is difficult if not impossible. However, data obtained over the last three seasons, when considered in its entirety, does provide a representative picture of the range and averages of pollutants in various types of discharge from cruise ships.

Sampling could be improved by de-emphasizing the importance of analyzing fecal coliform within 6 hours and increasing efforts to obtain representative sample sub-sets or composite samples of actual discharge taken over time. Recommendations for improving sampling are presented in Section XI.

Advanced treatment systems recently installed on several large cruise ships are very effective at removing solids and fecal coliform bacteria but these systems concentrate sludge that requires disposal. These treatment systems are not designed to remove priority pollutants but test results show that they do remove a significant portion.

Macerator-chlorinating systems have shown improvement in reducing fecal coliform on vessels with less than 1000 passengers and crew but in some cases have a high chlorine residual and chemical oxygen demand.

The 2000 large ship data shows that none of the conventional biological treatment systems were functioning properly. Ships with this type of treatment system are not currently discharging in Alaska waters.

III. Assessment of Fecal Coliform Bacteria in Cruise Ship Wastewater Discharge

The Panel determined that the relevant scenarios of exposure to large cruise ship discharges include secondary contact recreation by fishermen, kayakers, and motor-powered watercraft crossing a cruise ship wake shortly after passage of the cruise ship, and raw shellfish consumers harvesting shellfish along the shoreline. The available data, coupled with the relevant dilutions, indicate that violations of the applicable bacterial water quality standards are not predicted to occur for any of these scenarios.

IV. Potential for Nutrients in Wastewater to Promote Unwanted Phytoplankton Blooms in Receiving Waters

The limiting nutrient for phytoplankton growth in Southeast Alaska marine waters is dissolved nitrogen. The Panel estimates the maximum mean total nitrogen concentration in large cruise ship wastewater discharges to be 5 millimoles (5 mM) or 0.07 mg/liter. By applying a minimum mixing factor of 50,000 for a moving cruise ship, the wastewater total nitrogen concentrations are one-tenth to one-hundredth of the lowest Alaska marine water background concentration, or about 0.1 micromoles (μM). This amount of nitrogen can be converted to a very small amount of phytoplankton over the next several days, approximately 0.03 micrograms of chlorophyll per liter. This amount of chlorophyll is only a hundredth to a thousandth of the standing phytoplankton. New treatment requirements and regulations for 2003 may further reduce the amount of nutrients discharged in cruise ship wastewaters.

V. Effect of Cruise Ship Discharges on the Quality of Marine Sediments

Contaminants in cruise ship discharges were evaluated, focusing on metals and total suspended solids effluent data. Estimates of metals in the suspended solids were compared directly to sediment guideline values and some metals were shown to exceed sediment guideline values in the suspended solids. Copper, the contaminant that exceeded guideline values most often, was selected for evaluation. The incremental increase in copper sediment concentrations resulting from cruise ship particulates combined with natural deposition of particles was quantified for several conservative scenarios and compared to sediment guideline values and background sediment copper concentrations. The Panel concluded it was unlikely that there would be environmental impacts of contaminants in sediments that could be associated directly with cruise ships.

VI. Impacts to the Surface Water Microlayer of the Marine Environment

The Panel investigated the possibility that contaminants from large cruise ship wastewater discharge might adversely impact life-form activity in the 200-300 μm thick microlayer or sea surface film. The Panel concluded that the high dilution of wastewater caused by a large moving cruise ship would prevent significant accumulation of contaminants in the microlayer, even after accounting for the sequestering or enrichment properties of the microlayer. Small cruise ships that discharge small amounts of wastewater while anchored or stationary in fjords and embayments may have some limited potential for adverse impact to the fresh water layers found in fjords and embayments.

VII. Criteria for Delineating Areas Potentially Sensitive to Cruise Ship Wastewater Discharges

The Panel considered sensitive areas and sensitive species in attempting to determine whether certain waters and nearby shorelines might be more sensitive than others to cruise ship discharges.

The Panel developed three recommendations for cruise ship discharges:

1. Stationary discharge in a low tidal exchange area could lead to water quality issues and should be avoided.

2. The current requirements for large cruise ships – wastewater discharge at a minimum speed of 6 knots and at least 1 nautical mile from shore unless they can meet the strict effluent standards for stationary discharge – is good management practice and should be practiced by all passenger ships.

3. No discharges should occur within 0.5 nautical mile from areas of commercial bivalve shellfish beds.

The Panel set forth two recommendations for identifying sensitive areas:

1. At this time, the Panel is not aware of any species that has a sensitive life stage that crosses cruise ship discharge areas. However, should such a species be identified it could be an important issue for cruise ship discharge timing in a particular location.

2. Areas where long residence time or minimal neap tidal exchanges occur are areas where chemicals from wastewater discharges are a potential issue. Tidal exchange information could be used to prioritize areas for further study to determine whether or not wastewater discharge is a problem.

VIII. Sources of Shipboard Chemicals and Pathways by which They Could Reach the Marine Environment

Between May 2000 and September 2002, members of the Science Panel attempted to develop a good working knowledge of the likely "universe of chemicals" brought on board and used on large cruise ships. They visited several large ships – spending two days underway on one – and conducted extensive interviews with corporate managers, officers and crew. Eight possible pathways whereby onboard chemicals could be discharged to the environment were identified and evaluated. The Panel concluded that a properly maintained, well-managed, modern cruise ship, operating in full compliance with government regulations, will not release shipboard chemicals into the environment at a quantity or level that will cause measurable negative environmental impact. The authors suggest monitoring several additional chemicals in the future for the purposes of validating best practice or dilution models.

IX. Small Commercial Passenger Vessels

The small fleet discharges 6% of the total wastewater discharged into Alaska waters from passenger vessels. This number includes the ferries that operate year round. The Panel has noted that significant mixing and dispersion occurs when wastewater is discharged from a

moving vessel. Small ship discharges, occurring while at anchor or in port, do not benefit from the mixing dynamic of underway discharge. Stationary treated blackwater and graywater discharge, especially at the head of fjords, embayments and other areas of low net marine water outflow, should be avoided (Sections VI, VII).

The macerator/chlorinating system (Section II) when used on small ships has demonstrated the ability to treat wastewater effectively for bacteria and total suspended solids. However, this is achieved by the use of high levels of chlorine. Chlorine is an effective disinfectant but excessive chlorine residual is toxic to marine life. The State of Alaska should consider whether a residual chlorine standard is necessary to prevent excessive chlorine entering the marine environment.

Sample results from biological treatment show that this treatment system, as currently operated on board small ships, cannot meet effluent standards for bacteria and suspended solids.

Evaluation of small cruise ship impacts, including a risk-screen, should continue.

X. Marine Water Monitoring Needed to Track the Impacts of Wastewater Discharges

Every two years in the spring, the National Status and Trends Program (NSTP) of the National Oceanic and Atmospheric Administration (NOAA) samples mussels for contamination at five Alaska coastal sites. As expected, organic chemicals and trace metals concentrations are much lower at these sites than elsewhere along the US Pacific coast. However, more data from Alaska coastal sites are needed, at the right time (summer), to determine if passenger vessel activity is a relevant contributor to coastal contamination. Environmental monitoring provides a check that regulatory actions have their intended benefit and reduces uncertainty. Although the Panel believes cruise ships are not likely to contribute measurable contamination, a slightly-enhanced monitoring of contaminants in mussels and sediments in Southeast Alaska, Prince William Sound, along the Kenai Peninsula, and in Cook Inlet, during the tourist season, could provide a valuable tool in assuring that state coastal waters remain relatively uncontaminated.

XI. Recommendations for Research and Program Improvements

The Panel finds that, while the risk of environmental impacts from current discharge practices is low, continued targeted research monitoring increase the level of certainty. Specific recommendations within the following program and research categories are set forth in Section XI:

Continued Evaluation of Small Passenger Vessels

Improved Sampling and Additional Audits of Passenger Vessels

Determining Water Movement and Exchange in Selected Coastal Areas

Enhanced Environmental Assessment and Monitoring of Alaska Waters

XII. Best Management Practice and Recommended Policies

In addition to recommendations for monitoring and research, the Panel suggests three best management practices and policies for risk minimization. They are:

Policies to encourage small cruise ships to discharge wastewater while underway.

Policies to prevent over-chlorination.

Best management practices for large cruise ships with advanced wastewater treatment systems.

Alaska Department of Environmental Conservation

Science Advisory Panel

Commercial Passenger Vessel Environmental Compliance Program

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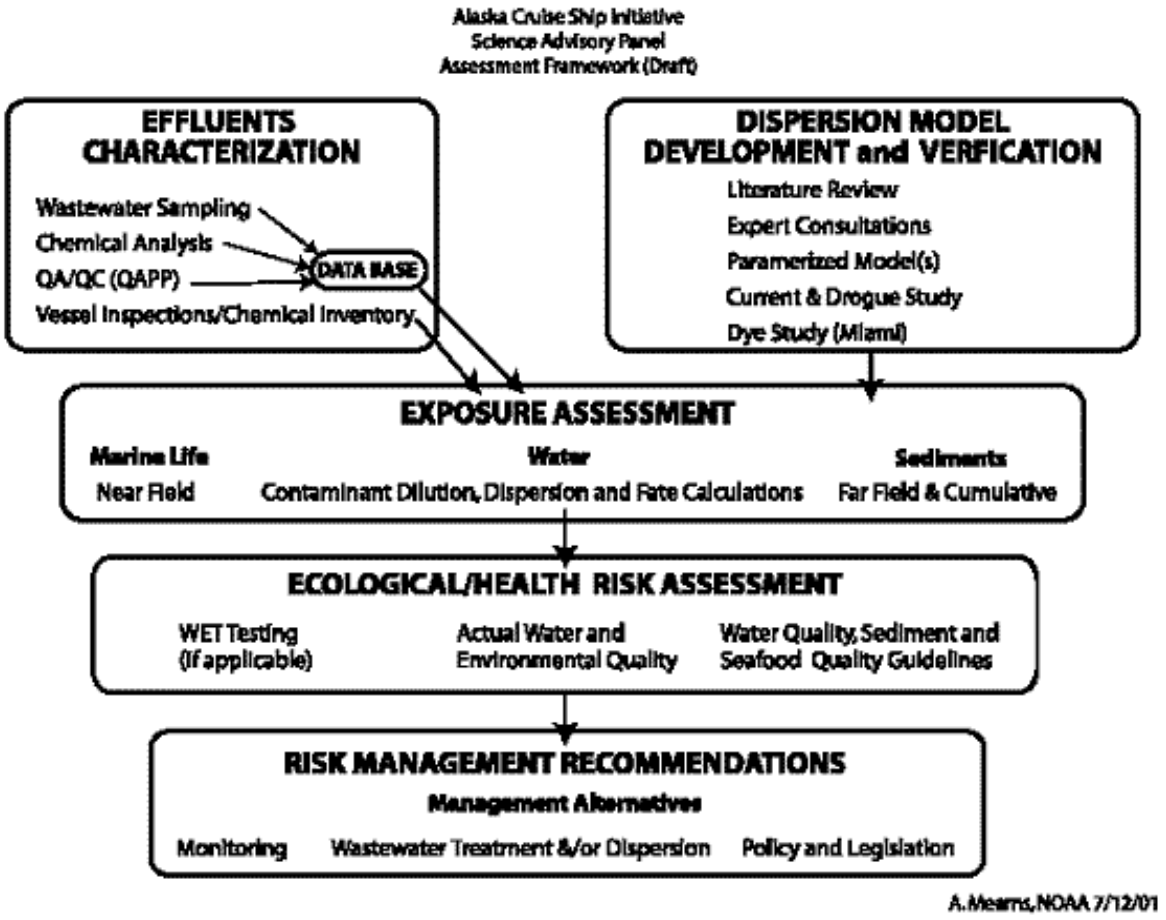


Figure I
A discussion of the development and use of the assessment framework is provided in Appendix I.

Section I

Dilution of Wastewater Discharged by Large Cruise Ships

Lincoln Loehr, CJ Beegle-Krause, Kenwyn George, Charles McGee, and Alan Mearns

Summary

The study, by itself, of effluent characteristics is not sufficient to evaluate exposure and ecological/health risks associated with cruise ship wastewater discharge. An understanding of dilution is essential. The Science Advisory Panel (the Panel) has undertaken a number of efforts with the goal of developing a simple method of estimating wastewater dilution in the wake of a moving large cruise ship[2]. Starting in February 2001 and continuing through September 2002 the Panel has:

Reviewed several published wake mixing studies [Colonell et al. (2000), Curtis et al. (1999), Csanady (1980), Kim (2000), ESL (2000)];

Developed a preliminary conservative description of wastewater dispersion behind moving large cruise ships [Science Advisory Panel June 26, 2001];

Made direct observations of the depth and width of turbulence behind several cruise ships [Loehr et al. 2001];

Had one member observe dye studies of four cruise ships off of Miami conducted by the EPA, and

Reviewed EPA's final report on the Miami cruise ship dye studies [EPA 2002].

The Panel has determined that the dilution occurring within the first 15 minutes following the discharge of wastewater behind a moving large cruise ship is a function of the speed of the vessel, the rate of discharge, the beam (width) and draft (depth) of the vessel. Vigorous mixing occurs in the turbulent wake and extends horizontally beyond the beam (or width) and vertically below the draft (or depth) of the vessel. For a large cruise ship discharging at a rate of 200 cubic meters per hour and traveling at the minimum allowed speed of 6 knots, the mixing will be greater than 50,000 to 1. Different speeds, discharge rates, and hull sizes can result in different mixing rates and can be reasonably determined by the following formula:

Large Cruise Ship

Dilution factor = 4 x (ship width x ship draft x ship speed)/(volume discharge rate)

[2] A large cruise ship is defined in Alaska Statute 46.03.490 as a commercial passenger vessel that provides overnight accommodation for 250 or more passengers for hire, determined with reference to the number of lower berths. Federal regulations written specifically for cruise ships operating in Alaska waters (33 CFR 159, Subpart E) apply to vessels with accommodations for 500 or more passengers. In this document, we are using the state definition of large cruise ship.

$$=4x\ (\_\_\_\_\_m \quad x \quad \_\_\_\_\_m \quad x \quad \_\_\_\_\_m\ sec^{-1})/(\_\_\_\_\_m^3 sec^{-1})$$

This formula is quite straightforward. A ship with a large cross sectional area (draft and width) will create more mixing than a smaller ship. A ship moving faster will discharge less effluent per meter traveled than a ship moving at a lesser rate. A ship discharging at a slower rate of discharge will also discharge less effluent per meter traveled. Decreased effluent discharged per meter traveled leads to greater dilution.

In Alaska, fecal coliform colonies in graywater and blackwater discharges from large ships may not exceed 200 per 100 ml and total suspended solids may not exceed 150 mg/L and must be discharged while the vessel is traveling at a minimum speed of 6 knots and is at least 1 nautical mile from shore.[3] A large cruise ship may discharge at any speed and location if they meet much more stringent effluent standards.[4] Far field dispersion processes assure that additional dilution will occur before any mixture of effluent and water approaches a shore. Under the least favorable conditions, the additional dilution factor will be 100 by the time the mixed water reaches the shoreline, thus diluting the effluent of the vessel discharging at 200 m^3 /hr at 6 knots by a dilution factor of 5,000,000 or 50,000 x 100.

Utilizing the large ship studies and two studies of smaller ships, the Panel developed the following formula for small commercial passenger vessels:

Small Cruise Ship

Dilution factor = 3 x (ship width x ship draft x ship speed)/(volume discharge rate)

$$=3\ x\ (\_\_\_\_\_m \quad x \quad \_\_\_\_\_m \quad x \quad \_\_\_\_\_m\ sec^{-1})/(\_\_\_\_\_m^3 sec^{-1})$$

In this section and in later sections of this report, effluent observations from a variety of vessels will be discussed and evaluated in the context of the dilution estimations outlined above. This in turn allows evaluation of the effects of toxicants, bacteria, nutrients and toxicity on the marine waters and sediments of Alaska.

Significance

Simply looking at effluent bacteriological, chemical, suspended solids or whole effluent toxicity data from cruise ship discharges is not sufficient to evaluate exposure and ecological/health risks associated with a discharge. An understanding of dilution is essential. Point source discharges such as municipalities and industries are regulated under a permitting program that includes routine evaluation by permitting authorities (EPA or states) to determine whether they have a reasonable potential to exceed water quality standards after consideration of dilutions attained at allowed mixing zone boundaries. If that permitting process determines there is a reasonable potential to exceed any water quality standard, then water quality based effluent limits for those specific parameters are imposed. If that permitting process determines there is no reasonable

[3] Alaska Statute 46.03.463(b) &(c).

[4] The standards established by US Title XIV – Certain Alaska Cruise Ship Operations 1404(c) require that ships must meet the following effluent discharge standards in order to discharge continuously: (1) the discharge satisfies the minimum level of effluent quality specified in 40 CFR 133.102; (2) the geometric mean of the samples from the discharge during any 30-day period does not exceed 20 fecal coliform/100 ml and not more than 10 percent of the samples exceed 40 fecal coliform/100 ml; (3) concentrations of total residual chlorine may not exceed 10 mg/l.

potential to exceed, the discharge is determined to not be a water quality problem. While cruise ships are not regulated under the same permitting program, a similar evaluation approach is relevant for determining whether there is a reasonable potential for impacts from cruise ship discharges.

Initial approach to evaluating dilution

The Panel considered previous observational studies and modeling efforts and concluded that there would be considerable mixing when wastewater was discharged from a moving vessel, due to the speed of the vessel, the rate of the discharge, the turbulence associated with the passage of the hull through the water, and the propeller action. The Panel submitted a report on June 26, 2001 (Science Advisory Panel 2001) that:

1. Reviewed various studies (Colonell et al., 2000; Csanady, 1980; Kim 2000; ESL, 2000) that generally identified very high rates of dilution based on theoretical calculations and/or observations,

2. Recommended a dye dispersion study as the most definitive means to answer the dilution questions, and

3. Advanced a simple formula approach to provide a conservative estimate of mixing that would occur within less than 15 minutes[5] following discharge. This formula allowed the Panel and others to continue a conservative impact analysis while awaiting the results of the EPA Miami dye study.

Calculated dilution factors for three different, large cruise ships at 6, 12 and 18 knots with assumed discharge rates of 200 cubic meters per hour were presented in the report and varied from 10,500 to 39,600. Even though these were very substantial dilution factors and represented mixing that occurs in a very short period of time, the panel emphasized that dilutions calculated in this manner were conservative.

The June 26, 2001 report also looked at the maximum and average concentrations of toxicants observed in the Summer 2000 Alaska cruise ship wastewater sampling program[6], calculated the toxicant concentrations (for detected priority pollutants) after a representative dilution factor of 12,000 and compared the values to Alaska's water quality standards. Although not specifically

[5] EPA's Technical Support Document for Water Quality-based Toxics Control (EPA/505/2-90-001) describes how an acute mixing zone should be established to prevent lethality to passing organisms. The guidance recognizes that the water quality criteria include duration of exposure considerations. Specifically, EPA allows that a drifting organism should not be exposed to 1-hour average concentrations exceeding the acute criteria, and that if travel time for a drifting organism through the acute mixing zone is less than 15 minutes, then a 1-hour average exposure would not be expected to exceed the acute criterion. The same demonstration is allowed for in Alaska's Water Quality Standards. This is the reason that the Science Advisory Panel has selected the time of 15 minutes following a cruise ship's passage as the basis for comparing to acute water quality standards. Comparison to more stringent chronic water quality standards, including whole effluent toxicity tests at the 15 minute dilutions would be conservative and protective as well. Comparison to mixing after 15 minutes is also appropriate for evaluating incidental bacteria exposures for the infrequent scenario of a kayaker more than a mile from land crossing the wake behind a cruise ship.

[6] Alaska Cruise Ship Initiative Part 2 Final Report (June 1 2000 to July 1, 2001). The report can be accessed at http://info.dec.state.ak.us/decpermit/acsireport.pdf

stated, the effluent concentrations and the dilution showed that there was no reasonable potential for any of the measured toxicants to exceed a water quality standard after initial mixing.

Science Advisory Panel observations

In July 2001, the Panel met in Juneau and toured a number of large cruise ships. The panel also conducted a current and wake turbulence study of opportunity, measuring currents at various depths in the wake of two cruise ships and video taping the fathometer to record detailed observations of the depth and width of turbulence behind the cruise ships (Loehr et al., 2001). The current studies identified considerable variability in current directions over the water column, indicative of shear effects contributing to mixing. Fathometer observations showed that the turbulence from the passage of the cruise ships initially extended well below the 8 m hull depth of the cruise ships, and the width of the turbulence spread to 125 m within 6 to 9 minutes. The wake turbulence zone then grew gradually wider and shallower over time as it rose and spread horizontally.

The current and turbulence observations provided the Panel information supporting more than three times the mixing that was calculated by the formula developed by the panel. The panel also pondered whether a discharge along the side of the hull, rather than from beneath the hull, would make a difference to the dilution achieved. Later dye study results from EPA indicated that this did not appear to make a difference.

Navy studies

By the December 2001 meeting of the Panel, copies of studies by the Navy behind a frigate, measuring dilution of a pulped waste paper discharge released from the stern were available (Curtis et al., 1999). The studies included observations of dye as well as pulp, and provided good agreement with numerical modeling performed by the Navy. This frigate had a single propeller. The Panel looked at the hull width and depth of the frigate, the frigate's speed, the discharge rate, and compared the Navy's mixing results with the panel's conservative formula. The Navy study measured and modeled dilutions about 3 times greater than what the Science Advisory Panel's conservative formula predicted.

EPA dye studies

In August 2001, EPA conducted dye dispersion studies behind 4 large cruise ships off the coast of Miami and a draft report was released to the panel in July 2002 (EPA, 2002). One member of the Panel was an onboard observer during EPA's studies. Because these observations were of actual cruise ship wastewater discharges, the EPA observations provided the best reference for estimating a factor to apply to the Panel's formula. One of the cruise ships had an azipod propulsion system (motors and propellers with a shroud around them) and three of the cruise ships had more conventional propeller arrangements. The dye studies provided "measured" initial dilutions and "calculated" initial dilutions. The Panel compared EPA's measured and calculated initial dilutions with the dilutions predicted by the conservative Science Advisory Panel formula. The measured mixing values were 5.3, 0.9, 6.5 and 5.1 times that predicted by the formula. The calculated mixing values were 4.7, 4.2, 6.7 and 4.5 times that predicted by the

formula (hence the factor of 4 in the large cruise ship dilution formula now endorsed by the Panel).

For the *M/V Explore*r the measured mixing value was only 0.9 times the conservative Science Advisory Panel formula and was anomalous to the other results from the other cruise ships. The Panel initially attributed it to the ship's unique azipod propulsion and also its hull design that would pull deeper water into the azipods. The hull at the stern had twin concave arches within which the azipods resided. Further analysis of the EPA study by the Panel lead them to conclude that the dye in the tank could not have been completely mixed and must have initially discharged at a much higher concentration than was intended. This analysis was achieved by a "mass-balance" calculation comparing the amount of dye discharged per meter traveled to the dye in the water after the ship passed. At the rate of discharge of the effluent, such high dye concentrations as observed would not have been possible had the dye been fully mixed within the tank. When the area in which dye was detected was considered in the later transects behind the ships, bearing in mind that there is quite a variation for each cruise ship, the dilution achieved behind the *Explorer* was reasonably close to that observed for two of the other ships. After a few hours the dye extended to a similar cross sectional area in the ocean as for two other vessels, indicating that a similar dilution would be achieved for the *Explorer*. The "measured" dilutions assumed a uniform dye concentration in the discharge, and for the *Explorer*, that clearly was not the case. Therefore, only the "calculated" dilution for the *Explorer* was used in the Panel's analysis.

Final recommended dilution factors

The formula now recommended by the Panel to describe the dilution for large cruise ships is:

Large Cruise Ship

$$\text{Dilution factor} = 4 \times (\text{ship width} \times \text{ship draft} \times \text{ship speed}) / (\text{volume discharge rate})$$

$$= 4 \times (\_\_\_\_\_ m \times \_\_\_\_\_ m \times \_\_\_\_\_ m\ sec^{-1}) / (\_\_\_\_\_ m^3 sec^{-1})$$

Since this formula accounts for ship size, speed and wastewater discharge rate it can be applied to a number of situations involving actual discharges underway. It can also be used to develop best operating practices. Further ship and discharge specific modeling or dye studies are not necessary for large cruise ships. Provided the vessel has holding tanks, discharges below the surface, and restricts their discharging to when they are moving, use of this simple formula approach for estimating dilution is sufficient and appropriate. No single dilution factor is pertinent for all discharges from all cruise ships.

Dilution will vary with the rate of discharge, the speed and size of the vessel.

Based on the 3 usable "measured" mixing values and four usable "calculated" mixing values determined from the EPA dye studies, the Panel believes a mixing multiplier of 4 can be conservatively applied to the formula first suggested by the Panel. Table I-1 illustrates how the EPA dye studies compared with the original Science Advisory Panel formula, and how the dye studies compare with the Panel's final formula. Note that computed values using the Panel's formula above match well with the dye study data. Since the dye study results include observations in which both the discharge rates and the speed of the vessels varied by a factor of 2

(9 to 19 knots and 56 to 112 cubic meters per hour discharge rate), the formula with the mixing multiplier of 4 is reasonable to apply to various size, speed and discharge rates.

The original Science Advisory Panel formula was identified as conservative and assumed that the volume of water involved in mixing was limited to a rectangle defined by the vessels width and depth and the length of the track over the time of discharge. By applying a factor of four to the formula, the Panel acknowledges that the cross sectional area of the mixing volume is at least four times the cross sectional area defined by the width and depth of the vessel. This is consistent with visual surface observations of ship's wakes, vertical observations of turbulence behind cruise ships using a fathometer, EPA's dye study results and other reported studies reviewed by the Panel.

Table I-1: Science Advisory Panel's Original Formula

Science Advisory Panel's original formula compared to EPA "measured" and "calculated" results from four dye studies.

Vessel Name		***Majesty***	***Explorer***	***Paradise***	***Fascination***
Width (beam)	m	32.6	38.6	31.4	31.4
Depth (draft)	m	7.7	8.8	7.75	7.75
Speed	knots	17.4	19	15	9.1
Speed	m/sec	8.96	9.78	7.72	4.68
Discharge Rate (Actual)	m3/hr	112	56	68	72
Discharge Rate	m3/s	0.031	0.016	0.019	0.020
Original Formula	Dil'n factor	72,270	213,577	99,479	56,998
EPA "measured"	Dil'n factor	386,057	195,322	643,810	288,412
Difference	factor	5.3	0.9	6.5	5.1
EPA "calculated"	Dil'n factor	342,123	907,547	666,667	255,499
Difference	factor	4.7	4.2	6.7	4.5

[NOTE: measured value for Explorer is suspect. The Science Advisory Panel believes dye did not mix well in tank.]

As above, but the Science Advisory Panel's original formula is adjusted by a mixing multiplier of 4 based on dye studies.

Vessel Name		***Majesty***	***Explorer***	***Paradise***	***Fascination***
Width (beam)	m	32.6	38.6	31.4	31.4
Depth (draft)	m	7.7	8.8	7.75	7.75
speed	knots	17.4	19	15	9.1
speed	m/s	8.96	9.78	7.72	4.68
discharge rate	m3/hr	112	56	68	72

Science Advisory Panel's original formula compared to EPA "measured" and "calculated" results from four dye studies.

Vessel Name		***Majesty***	***Explorer***	***Paradise***	***Fascination***
discharge rate	m3/s	0.031	0.016	0.019	0.020
Final Formula	Dil'n factor	289,081	854,309	397,918	227,992
EPA "measured"	Dil'n factor	386,057	195,322	643,810	288,412
difference	factor	1.3	0.2	1.6	1.3
EPA "calculated"	Dil'n factor	342,123	907,547	666,667	255,499
difference	factor	1.2	1.1	1.7	1.1

Appendix 2 uses the Panel's final formula for large cruise ships to calculate the diluted effluent constituent concentrations discharged from 21 cruise ships in 2000. The usefulness of such a formula is apparent when considering different discharge rates. The June 26, 2001 Science Advisory Panel report calculated dilutions on the basis that all discharges occurred at the same rate of 200 m^3 per hour. One of the more disturbing observations from the year 2000 cruise ship sampling was that some tanks had very high fecal coliform bacteria, biochemical oxygen demand (BOD) and total suspended solids (TSS) values. The highest BOD and TSS are found in galley waste tanks and occur because cruise ships practice water conservation. Water in the galley waste tank is reused in support of food waste grinder operations so of course the solids and BOD will be quite high in the galley waste tanks. Galley waste tanks are generally much smaller than the other waste tanks (20 to 30 m^3 compared to about 100 m^3), and are usually pumped with smaller pumps at around $1/10^{th}$ the discharge rate of the larger tanks. Even though the concentrations in the galley tanks are greater, so too is their dilution if they are discharged at a lower rate.

Table I-2 presents representative dilution calculations for a hypothetical large cruise ship with a beam of 30 meters, a draft of 8 meters, discharge rates of 200 m^3/hour (for large holding tanks) and 20 m^3/hour (for small holding tanks like galley wastes). The calculations were for speeds of 6, 12 and 18 knots. Dilution factors for the high discharge rate (200 m^3) varied from over 53,000 to over 160,000 for the range of vessel speeds. Dilution factors for the low discharge rate (20 m^3) varied from over 530,000 to over 1,600,000 for the range of vessel speeds. With the studies and data to date, the Panel is confident that the formula for dilution can be used for a vessel traveling down to 6 knots.

Table I-2: Final Applied Dilution Formula for Hypothetical Ship

Final formula applied to a hypothetical ship of 30 m wide, 8 m deep, at speeds of 6, 12 and 18 kts first using a 200 m^3/hr discharge rate and then using a 20 m^3/hr discharge rate

200 m^3/hr discharge rate example

Width (beam)	m	30	30	30
Depth (draft)	m	8	8	8
Speed	knots	6	12	18

Speed	m/s	3.09	6.18	9.27
Discharge Rate	m3/hr	200	200	200
Discharge Rate	m3/s	0.006	0.006	0.006
Modified SAP Formula	Dil'n factr	53,372	106,744	160,115
20 m^3/hr discharge rate example				
Width (beam)	m	30	30	30
Depth (draft)	m	8	8	8
Speed	knots	6	12	18
Speed	m/s	3.09	6.18	9.27
Discharge Rate	m3/hr	20	20	20
Discharge Rate	m3/s	0.006	0.006	0.006
Modified SAP Formula	Dil'n factr	533,718	1,067,436	160,1154

Table I-3 applies the final formula to the four large cruise ships that participated in EPA's dye studies to derive the dilution factors for speeds of 6, 12 and 18 knots based on the actual rates of discharge.

Far-field Dilution

Dilution factors associated with discharges from moving cruise ships are very large and occur very rapidly. For comparison, dilution factors available for typical municipal discharges may range from less than 10 to several hundred. In Alaska, large cruise ships are required to either treat wastewater to a level that meets stringent effluent standards or discharge while moving at a minimum speed of 6 knots at a distance one nautical mile from the shoreline[7].

The public has expressed concerns regarding the concentration of effluent that might reach the shoreline from 1 nautical mile – the closest to shore that large cruise ships without advanced treatment systems can discharge. There are several hydrographic and physical oceanographic processes that could result in this type of transport. Currents typically flow parallel to the shore rather than toward shore, but the rising and falling of the tides can transport water across areas of mudflats and marshes. Eddies and wind induced surface flows can also result in transport toward or away from the nearshore. An onshore wind would only move the very surface of the water (upper 1-10 cm) toward the shore. Wind driven surface currents are typically 3.5 % of the surface wind speed. The faster the wind blows, the faster any surface water would reach the shoreline, however, the surface wave mixing also increases with wind speed.

[7] Title 33, US Code of Federal Regulations Part 159.309 and Alaska Statute 46.03.463(b), (c), & (g).

For a modest 10-knot wind blowing directly on shore, almost 3 hours would be required to move surface water 1 nautical mile[8]. Assuming a layer 1 cm thick is moved by the wind and mixed into the wave influenced surface layer of about one meter, the additional mixing ratio would be 1 cm:1 m or 1:100 (a dilution factor of 100). Over a longer period of 24 hours, the water would mix completely through the mixed layer (about 10 meters) increasing the dilution factor from 100 to 1000. Over several days water moves in and out of the mixed layer causing further dilution. These estimates are conservative as the surface layer would likely mix even more and the water would not take a direct line to shore, but a more circuitous path longer in time due to local currents and eddies.

Table I-3: Final Dilution Formula Applied – Four Large Cruise Ships

		Large Vessels		
Majesty	*Gray water discharge at 112 m3/hr*			
Width (beam)	*m*	32.6	32.6	32.6
Depth(draft)	*m*	7.7	7.7	7.7
Speed	*knots*	6	12	18
Speed	*m/sec*	3.09	6.18	9.27
Discharge Rate	*gpm*			
Discharge Rate	*m3/sec*	0.031	0.031	0.031
Final Formula	*Dil'n factor*	**99,683**	**199,366**	**299,049**
Explorer	**Black water discharge at 56 m3/hr**			
Width(beam)	m	38.6	38.6	38.6
Depth(draft)	m	8.8	8.8	8.8
Speed	knots	6	12	18
Speed	m/sec	3.09	6.18	9.27
Discharge Rate	gpm			
Discharge Rate	m3/sec	0.016	0.016	0.016
Final Formula	Dil'n factor	**269,782**	**539,564**	**809,345**
Paradise	**Gray water discharge at 68 m3/hr**			
Width(beam)	m	31.4	31.4	31.4
Depth(draft)	m	7.75	7.75	7.75
Speed	knots	6	12	18
Speed	m/sec	3.09	6.18	9.27
Discharge Rate	gpm			

[8] 1 nm/(10 nm hr^{-1}*0.035) = 2.9 hours

Large Vessels

Majesty	*Gray water discharge at 112 m3/hr*			
Discharge Rate	m3/sec	0.019	0.019	0.019
Final Formula	Dil'n factor	**159,167**	**318,334**	**477,501**

Applicability of Formula to Small Cruise Ships

Fascination	**Gray water discharge at 72 m3/hr**			
Width(beam)	m	31.4	31.4	31.4
Depth (draft)	m	7.75	7.75	7.75
Speed	knots	6	12	18
Speed	m/sec	3.09	6.18	9.27
Discharge Rate	gpm			
Discharge Rate	m3/sec	0.020	0.020	0.020
Final Formula	Dil'n factor	**150,324**	**300,649**	**450,973**

Most data gathered on dilution behind moving vessels have been collected from large cruise ships. However, there are data from both a single propeller frigate (Curtis et al. 1999) and from a towed barge (Csanady, 1980). The data from both these vessels indicate that large dilution factors occur, for the frigate one can use a multiplier of 3 instead of 4 in the dilution formula. Because of these results, and because one would expect similar hydraulic characteristics between moving large and small vessels, only of a different magnitude, the Panel is fairly confident that the formula could be used with the multiplier modification to calculate dilutions behind small cruise ships. If there is a concern about a particular pollutant at the calculated dilution, then further analysis or studies could be done at that time on the small vessel. If there is no particular concern, then use the formula for small cruise ships with a multiplying factor of 3, as:

Small Cruise Ship

Dilution factor = 3 x (ship width x ship draft x ship speed)/(volume discharge rate)

=3x (_____m x _____m x _____m sec^{-1})/(_____m^{3}sec^{-1})

References

Colonell, J.M., S. V. Smith and R. B. Sipes. 2000. Cruise Ship Wastewater Discharge into Alaskan Waters. Technical Report 2000-01, Alaska SeaLife Center pp. 7-16

Csanady, G.T. 1980. An Analysis of Dumpsite Diffusion Experiments. pp. 109-129 B.H. Ketchum, D.R. Kester and P.K. Park (editors), Ocean Dumping of Industrial Wastes. Plenum Press, New York

Curtis, S.L., C. N. Katz and D. B. Chadwick. February 1999. Environmental Analysis of U.S. Navy Shipboard Solid Waste Discharges: Addendum to the Report of Findings. SPAWAR Systems Center San Diego Technical Report 1716,

ESL, LLC. 2000. Wastewater Dispersion Study: Distribution of Cruise Ship Effluent as Determined from Real-Time Collection of Water Column Samples; September 6-7, 2000

EPA Office of Water 2002. *Cruise Ship Plume Tracking Survey Report*

Kim, D.K. 2000. Cruise Ship Wastewater Dispersion Analysis (for International Council of Cruise Lines), August 25, 2000

Loehr, L.C., A. Mearns and K. George. August 6, 2001. Initial Report on the July 10, 2001 Study of Opportunity: Currents and Wake Turbulence Behind Cruise Ships. http://www.state.ak.us/local/akpages/ENV.CONSERV/press/cruise/documents/sciencepanel.htm

Science Advisory Panel for Commercial Passenger Vessel Wastewater Discharge. June 26, 2001. Report to the Alaska Cruise Ship Initiative. Near-Field Dispersion of Wastewater Behind a Moving Large Cruise Ship. http://www.state.ak.us/dec/press/cruise/documents/scipanl2.htm

Section II

Wastewater Sampling and Analysis for Commercial Passenger Vessels

Carolyn Morehouse, Charles McGee, Lincoln Loehr, and Michael Watson

Summary

Since July 1, 2001, Alaska law has required commercial passenger ships with at least 50 overnight passengers to take a minimum of two samples per year that are representative of wastewater effluent discharged in Alaska water. Wastewater includes blackwater (BW) from toilets and graywater (GW) produced from sinks, showers and laundry facilities. During the 2000 season, commercial ships under went wastewater sampling and analysis as a part of a voluntary program.

Over the last three years, the Alaska Department of Environmental Conservation (ADEC) received data from these sampling events. Obtaining truly representative sampling data for ships that do not discharge in port is difficult because the fecal coliform test has a 6-hour maximum holding time. Therefore, the wastewater sampled on these ships is representative of wastewater that can be sent to a lab within the 6-hour holding time rather than getting a sample of a majority of wastewater produced during the day.

Sampling could be improved by de-emphasizing the importance of analyzing fecal coliform within 6 hours and increasing efforts to obtain representative sample sub-sets or composite samples of actual discharge taken over time. Recommendations for improving sampling and sampling design are presented in Section XI and Appendix 3.

Small ships, vessels carrying 50-249 overnight passengers, do discharge in port but also have a difficult time obtaining representative samples. The ships port time is spent disembarking passengers and getting ready for the next cruise. There is usually little to no wastewater produced during this day in port, however this is where the sampling is done.

Obtaining samples on board a ship that is consistently representative of a discharge (particularly graywater) is difficult if not impossible. However, data obtained over the last three seasons, when considered in its entirety, does provide a representative picture of the range and averages of pollutants in various types of discharge from cruise ships.

The data show graywater has the same fecal coliform bacteria levels as blackwater. The data highlight the difference between wastewater that is collected and discharged immediately compared with wastewater that is held in tanks for later discharge. The data show the effectiveness of different treatment types.

The advanced treatment systems recently installed on several large cruise ships are very effective at removing solids and fecal coliform bacteria but these systems concentrate sludge that requires disposal. These treatment systems are not designed to remove priority pollutants but test results show that they do remove a significant portion.

The macerator chlorinator system has shown improvement in reducing fecal coliform on vessels with under 1,000 passengers and crew but in some cases has a high chlorine residual and chemical oxygen demand.

The 2000 data shows that none of the conventional biological treatment systems were functioning properly. Ships with this type of treatment system are not discharging in Alaska waters and therefore are not required to conduct sampling and analysis.

Background

Due to concerns regarding the quality and quantity of commercial passenger ship wastewater discharged into Alaska marine waters and the potential effects of those discharges, environmentalists, government agencies, the cruise ship industry, and other stakeholders formed the Alaska Cruise Ship Initiative in 1999. In 2000, this work group began a voluntary sampling program to test the effluents of large cruise ships that discharge in Alaska waters. Large cruise ships are defined as ships that have overnight accommodations for 500 or more people.

Commercial passenger ships produce two types of wastewater: blackwater and graywater. Blackwater is wastewater from ship's toilets and for the larger ships include medical facilities. Graywater is water produced from showers, sinks, and laundry. Graywater comes from three main sources: (1) galley or kitchen areas, (2) passenger/crew accommodations, and (3) laundry facilities. Anytime blackwater and graywater are combined the resulting wastewater is considered blackwater. For data comparison the gray and blackwater mix has been separated to see if its characteristics are different from other wastewater.

In June 2001, the Alaska legislature passed a law affecting commercial passenger ships operating in Alaska marine waters with overnight accommodations for 50 or more passengers.[9] The law set fecal coliform and TSS effluent discharge limits for both gray and blackwater.[10] It also allows the ADEC to perform necessary studies to determine if additional water quality limits are needed to protect human health and environment.

Cruise ship operators discharging wastewater in Alaska marine water sample for both conventional and priority pollutants. In 2002, the ADEC conducted a round of Whole Effluent Toxicity tests to determine the potential for effects of the effluent on marine organisms.

The ADEC compiled data from sampling events in 2000, 2001 and 2002. This report includes all data received by September 30, 2002. The ADEC developed tables that summarized the data.

For the tables, the ADEC, for statistical purposes, replaced zero or non-detect results with one-half (½) the minimum detection limit (MDL). The ADEC included tables for all pollutants with geometric means[11] greater than the MDL or where at least one sample result was over 10 times the detection limit. If all sample of a particular priority pollutant were non-detects, they were excluded from the table. This was done for the sake of brevity. Complete data sets are included in Appendices 5 & 6.

[9] Alaska Statute 46.03.460 - 490
[10] AS 46.03.463 set graywater and blackwater effluent standards for fecal coliform at 200 colonies per 100 ml and 150 mg per liter for total suspended solids.
[11] "Geometric mean" means the *nth* root of the product of a series of n numbers; eg. (2 x 9 x 5) ^1/3 = 4.48

Samples

Pollutants Analyzed

Wastewater sampling and laboratory analysis provides measurements of conventional and priority pollutants.

- All ships discharging in Alaska water were required to sample twice a year for the following conventional pollutants:
- Total Suspended Solids (TSS)
- Biochemical Oxygen Demand (BOD)
- Chemical Oxygen Demand (COD)
- Ammonia – Total
- Fecal Coliform
- pH
- Total and Free Residual Chlorine

In 2001, on the advice of the Science Advisory Panel, the conventional pollutants monitoring requirements were increased to include the following parameters:

- Settleable Solids (SS)
- Oil and Grease
- Total Organic Carbon
- Specific Conductance (to measure seawater influx)
- Alkalinity
- Total Nitrogen (Ammonia, Nitrate, Nitrite, and Total Kjeldahl Nitrogen (TKN))
- Total Phosphorus

One of the two required sampling events must sample wastewater for priority pollutants. Priority pollutants include:

- Base/Neutrals, Acids
- PCBs
- Volatile Organic Chemicals (VOCs)
- Trace Metals (Total Recoverable and Dissolved)

There are 126 so-called "priority" pollutants on the EPA list[12]. In 2000 and 2001, large ships sampled for all 126 pollutants. Since many of the priority pollutants were not discovered in these wastewater samples, the ADEC and United States Coast Guard (USCG) shortened the list to 55 pollutants in 2002. However, the 55 pollutants on the USCG list have 110 chemical constituents.[13] In order to reduce laboratory costs and under guidance from the Panel[14], the USCG and ADEC also removed every pesticide from the pollutant list in 2002.

Pesticides are used on vessels and some pesticide residue from fresh fruits and vegetables would be expected. In the absence of comprehensive shipboard audits, wastewater sampling in the

[12] The list used is from the *Compilation of the USEPA;s Water Quality Criteria for the Priority Toxic Pollutants* By Katy McKerney Sept 1997
[13] For example, the pollutant class PCB is actually comprised of seven PCBs.
[14] Wastewater Constituents to Monitor for 2001, Science Advisory Panel, August 2001 http://www.state.ak.us/dec/press/cruise/pdf/sciencepan061501.pdf

future should include pesticides. Appendix 4 contains the list of pollutants that were analyzed in 2002.

Sampling Strategy

The number and types of samples taken depended on individual ship configuration and the ability to get the samples to a laboratory for analysis within a 6-hour time frame. In 2000, the goal of the sampling program was to characterize the wastewater, determine if hazardous substances were discharged with the graywater, and determine the functionality of the wastewater treatment systems.

In 2000, large ships agreed not to discharge within 10 miles of the nearest port. Some of the 2000 in port samples were taken from holding tanks and Marine Sanitation Devices (MSD). The water in these holding tanks was not being discharged to the ambient water but instead held in double bottom (DB) or ballast tanks for later discharge. These 2000 sampling data were more representative of the wastewater that vessel's discharged prior to the 2000 agreement to "hold" water in port.

The other sampling events in 2000 sampled the double bottom holding tanks. These tanks held a majority of the water but could only be sampled as the ship was discharging to the ambient water. The wastewater in the double bottom tanks was being held for up to 20 hours and discharged once the vessel was more than 10 miles from port.

After the Federal legislation or the "Murkowski" bill passed in 2000 and the Alaska State law passed in June 2001, the purpose of the sampling shifted to assess compliance with the federal and state laws.[15]

In 2001, the wastewater samples from large ships had to be taken as the wastewater was being discharged overboard. Therefore, the large ship samples originated from collecting tanks because the ballast tanks discharge occurred more than 6 hours from port. Small ships sampled in port as they were discharging, but there were no people on board. The ferries' sampling occurred while there were stopped in Juneau, which typically lasted only 1-2 hours.

In 2002, the wastewater data from large ships reflects the increase in the number of large vessels that had installed advanced treatment technology, from two in 2001 to seven in 2002. Of the seven ships with advanced treatment, six met more stringent effluent standards[16].

The wastewater sampling strategy from small ships in 2002 was similar to that of 2001. Small ships took their first priority pollutant data in 2002.

[15] FederalTitle XIV—Certain Alaskan Cruise Ship Operations and Alaska Statute 46.03.460 -490

[16] More stringent standards are 20 fecal colonies per 100 ml of sample and TSS of 15 mg/L compared with 200 and 150 comparatively. The more stringent standards also include a chlorine residual limit of 10 mg/l.

Ships treatment systems from 2000 to 2002

Black water treatment

All large ships treat black water using a US Coast guard approved Marine Sanitary Device (MSD) or the black water is untreated and discharged when the ships are more than 12 miles from land. The MSD units use the following treatment systems: (1) biological treatment system, (2) macerator/chemical, or (3) advanced treatment.

Biological systems clarify the wastewater by allowing solids to settle then use aeration to encourage biological growth that feeds on the organic waste. Biological systems use either chlorine or ultraviolet light for disinfecting the final discharge.

Macerator/chlorinator systems dilute the wastewater about 10:1 with ambient seawater. A macerator pump breaks up any solids. An electrochemical cell generates chlorine from the seawater and this is used for final disinfecting. There are currently nineteen small ships and ferries in the program. Fifteen use this type of treatment system. Only the four largest of the small ships use a biological treatment MSD.

Advance treatment systems treat the wastewater using a biological process followed by ultrafiltration (filter pore size less than a fraction of a micron - one micron is one millionth of a meter) or reverse osmosis filtration. The advance treatment systems then use either chlorine or ultraviolet radiation to kill bacteria. Currently, only large ships are using advanced treatment systems.

Graywater treatment

Graywater is usually not treated. Some vessels mixed the graywater with the blackwater where it gets treated in the blackwater treatment system or advance treatment system. Some ships add chlorine to their graywater collecting tanks to achieve some level of bacteria reduction.

Data Analysis

In the following tables, the ADEC used one-half (½) the minimum detection limit (MDL) for results that are zeros or non-detects for statistical purposes. In this chapter the ADEC included tables for all pollutants with geometric means greater than the MDL or where at least one sample result was over 10 times the detection limit for the sake of brevity. Tables with all of the raw data are located in Appendices 1 - 5.

Small Ships

Alaska Statute defines small ships as commercial passenger ships that have overnight accommodations for 50-249 passengers. Five of the Alaska Marine Highway System (AMHS) ferries are defined as small ships under Alaska law.

All small ships treat blackwater in an USCG approved Type II MSD[17]. Most small ships operating in Alaska treat sewage using a macerating/chlorinating system; two of the largest small ships treat sewage with a biological system.

Small ships either collect graywater in tanks and then discharge using a pump, or discharge the graywater directly from drains to the ambient water. Some ships manage graywater using a combination of both practices. The graywater management practice depends on ship configuration. Most small ships do not have wastewater holding capacity.

The AMHS ferries and two small passenger ships mix their gray with the black water and treat both effluents with their MSD. Some small ships "treat" graywater with chlorine injection. Chlorine is effective for disinfecting but excessive chlorine residual may be toxic to marine life.

There were only three small ship samples taken from AMHS ferries in 2000, to few to analyze. In 2001, small ship samples were only analyzed for conventional pollutants. In 2002, the small ship samples were analyzed for both priority and conventional pollutants. Tables 1 through 4 include all sample data received by the ADEC by September 30, 2002. *The ADEC will prepare an Addendum to this paper that includes an analysis of all 2002 data.*

The data were separated into summary tables according to wastewater effluent type and type of treatment. The raw data tables are included in Appendix 5. The geometric mean values for the conventional pollutants are presented in Table II-1. The highest geometric means for fecal coliforms are associated with untreated mixed graywater followed by the mixed, treated black and graywater (BW&GW).

The limited laundry and galley graywater data shows low fecal coliform densities for these types of graywater. The data from a laundry-holding tank shows little to no bacteria growth occurring in that tank. The accommodation graywater only samples had two samples that were over 1000 fecal coliforms per 100 ml, but the geometric mean is low at 9 fecal colonies per 100 ml.

Table II-1 shows that the treated BW and BW/GW mixed had similar results except for ammonia, where the treated BW had much higher results. Obviously chlorine treated GW had lower fecal coliform bacteria counts than the untreated GW but it also had higher BOD and COD. Treated GW had higher TSS than untreated GW. The Panel has no explanation for this apparent abnormally.

In April 2002, the AMHS discovered that sampling had been occurring prior to the chlorinating stage. This explains the high fecal coliform count for samples taken prior to May 1, 2002. A separate review of the Alaska Marine Highway System (AMHS) is shown in Table II-2. Table II-2 shows that samples taken before May 1, 2002 have a fecal coliform geometric mean of 5,740 fecal bacteria per 100 ml of water compared to the geometric mean of 3 fecal bacteria per 100 ml for samples taken after May 1, 2002. This comparison shows that the correctly sampled samples have a slightly lower biological oxygen demand (BOD), lower chemical oxygen demand (COD) and higher chlorine residual

[17] A type II marine sanitation device is a device that under certain test conditions produces an effluent having a fecal coliform bacteria count not greater than 200 per 100 milliliters and suspended solids not greater than 150 milligrams per liter (Title 33 US Code of Federal Regulations Part 159, subpart A).

Table II-1: Small Ships: Summary Geometric Mean for Conventional Pollutants

2001 and 2002 data

# samples	All data	Wastewater Type	Ammonia	pH	BOD	COD	TSS	Total Cl	FREE CL	FECAL	CONDUCT
	From table		mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	MPN/100ml	Umhos/cm
14	Table B2	Treated Blackwater	31.500	7.65	21.51	1,004.3	97.6	0.30	0.15	1,546	37,400.0
19	Table B3	BW&GW mixed & treated	1.340	7.25	58.08	930.0	61.1	1.12	0.38	1,414	31,653.0
4	Table B4	Mixed Graywater (chlorine treated)	Not analyzed	7.90	382.70	880.4	186.9	78.62	58.72	1,225.	not analyzed
9	Table II-B4	Mixed Graywater (untreated)	7.290	6.97	95.42	228.3	52.9	ND	ND	99,096	53.12
10	Table B5	Graywater Accommodations	not analyzed	6.74	164.28	174.0	24.3	0.11	0.05	9.	not analyzed
2	Table-B6	Graywater Laundry	0.245	9.13	123.20	319.0	21.5	0.35	0.18	2	not analyzed
2	Table B7	Graywater Galley	not analyzed	Not analyzed	247.40	not analyzed	42.6	2.21	Not analyzed	50	not analyzed

Table II-2: Alaska Marine Highway System: Summary Geometric Mean for Conventional Pollutants

# Samples	All data	Time	Test	Ammonia	pH	BOD	COD	TSS	Total Cl	FREE CL	FECAL	CONDUCT
	From table			mg/L		Mg/L	Mg/L	Mg/L	Mg/L	mg/L	MPN/100ml	Umhos/cm
11	Table B1	AMHS from 2000 -April 2002	Geomean	8.880	7.37	81.15	875.0	50.8	0.67	0.14	5740	35,316.1
6	Table B1	AMHS May 2002-Present	Geomean	0.380	7.58	7.47	686.8	45.8	9.08	6.12	3	27,231.0

The small ships did not take any priority pollutant data samples in 2001. Analysis of priority pollutants in 2002 will be included in the forthcoming addendum.

Table II-3 shows the geometric means of the 2002 data for conventional pollutants, metals, and base/neutral/acids (BNAs).

Mercury, cadmium and silver (dissolved and total recoverable) and dissolved antimony were not detected in any sample and therefore, are not included in Table II-3.

The highest dissolved and total recoverable lead result of any sample was 1.21 µg/l and 6.74 µg/l, respectively. These values are less than 10 times the MDL so lead results were excluded from Table II-3. Dissolved and total recoverable Thallium results were not included because the geometric mean was less than the MDL. Table B9 in Appendix 5 includes the results from all pollutants.

Only seven of the 72 base/neutral/acids pollutants had any constituents above detection levels. Of the seven pollutants, only four (benzoic acid, benzyl alcohol, bis (2-ethylhexyl)phthalate, and diethylphthalate) had geometric means that were above the MDL or had at least one sample that was 10 times the MDL. Benzoic acid appeared in high levels. The maximum concentration of benzoic acid was 600 ug/L in one sample and the geometric was 63.4 ug/L compared with a MDL of 21 ug/L.

The mixed BW&GW samples had significantly higher levels of metals than the graywater sample. However, this comparison is statistically skewed because there is only one graywater sample. Further analysis of 2002 data will give a better indication of priority pollutant analysis.

Table II-4 shows the volatile organic compounds (VOCs) data for the same group of samples that were presented in Table II-3. These tables are broken apart only because of page space limitations.

There are no PCBs detected in any sample except for two surrogates added by the lab for Quality Assurance. PCB results are included in the Appendix 5 as Table B10.

Pollutants in Table B12 were included in Table II-4 if the geometric mean was greater than the MDL or at least one pollutant was 10 times the MDL. Twenty-two out of 75 pollutants were included as volatile organic compounds. The other 53 compounds were all below detection limits and not included in the analysis.

All the samples contained acetone. The acetone results ranged from 0.6 ug/L to 52 ug/L, with half of the samples containing at least 45 ug/L. All four mixed BW/GW samples contained bromoform at levels more than 100 times the MDL, while the treated blackwater sample and treated graywater samples were non-detects. The graywater sample had high levels of chloroform. Two of the four mixed BW&GW samples had chloroform levels over the detection limit. One of the mixed BW&GW was high in the rest of the detected VOCs. The other samples were below or close to the MDL.

Bromoform and chlorodibromomethane are formed as by-products when chlorine is added to kill bacteria.

The conventional pollutant analyses done concurrently with the priority pollutants analyses for samples in Table II-3 and Table II-4 have geometric means of 1.67 MPN/100 ml for fecal coliform, 38.51 mg/l for TSS, 6.19 mg/l for total chlorine, and 3.94 mg/l for free chlorine.

In summary, the wastewater sample data for small ships that the DEC received by September 30, 2002 contained the following priority pollutants:

- Benzoic acid
- Diethylphthalate
- Acetone
- Bromoform
- Chloroform
- Antimony (total recoverable)
- Arsenic (Dissolved and total recoverable)
- Copper (Dissolved and total recoverable)
- Selenium (Dissolved and total recoverable)
- Zinc (Dissolved and total recoverable)

Small ships did not participate in the voluntary 2000 sampling. They did not sample for priority pollutants in 2001. This analysis had to rely on the limited amount of priority pollutant data from 2002. We are, therefore, unable to draw broad conclusions characterizing the level of priority pollutants in the wastewater effluent of small ships at this time.

Table II-3: Small Ships – Conventional Pollutants, Detectable Metals and BNAs.

2002 data (All units of measure in µg/l unless noted)

Type	Ammonia as N mg/l	BOD-5 Day mg/l	COD mg/l	Conductivity umhos/cm	TSS mg/l	Fecal coliform bacteria by MPN/100 ml	Free Cl residual mg/l	PH (no units)	Total Cl residual mg/l	Arsenic Dissolved	Arsenic TR	Chromium Dis	ChromiumTR	Copper Diss.	Copper TR	Nickel Dis	Nickel TR	Selenium Dis.	Selenium TR	Zinc Dis	Benzoic Acid	Benzyl Alcohol	Bis(2-Ethylhexyl)Phthalat	Diethylphthalate
MDL	**0.160**	**1.00**	**0.3**	**1.0**	**0.1**	**2**	**0.10**	**0.10**	**0.1**	**1.3**	**3.6**	**1.9**	**2.3**	**1.0**	**1.2**	**1.5**	**1.1**	**4.2**	**4.8**	**2.5**	**21**	**0.58**	**0.69**	**0.88**
Mixed BW&GW	29.400	117.00	495.0	22,800.0	73.9	22	12.0	7.67	20	No metals were taken											220	8.00	2.10	3.70
Mixed BW&GW	**1.270**	**134.00**	**451.0**	**23,000.0**	**75.2**	**1**	**10.0**	**6.88**	**25**	**35.0**	**33.6**	**4.2**	**5.0**	**163.0**	**339.0**	**21.2**	**23.2**	**164.0**	**109.0**	**74.9**	**600**	**5.60**	**2.80**	**2.20**
Mixed BW&GW	**0.080**	**0.50**	**870.0**	**31,200.0**	**22.5**	**1**	**25.0**	**8.10**	**40**	**50.0**	**37.0**	**4.3**	**3.0**	**119.0**	**166.0**	**16.6**	**14.3**	**171.0**	**132.0**	**71.3**	**12**	**0.29**	**5.10**	**0.28**
Mixed BW&GW	**0.121**	**0.50**	**514.0**	**23,800.0**	**22.9**	**1**	**2.5**	**7.91**	**3.5**	**39.4**	**23.2**	**10.3**	**1.5**	**18.7**	**30.7**	**16.6**	**9.8**	**101.0**	**94.1**	**67.3**	**62**	**0.29**	**8.00**	**0.28**
TBW Blackwater	**6.320**	**5.47**	**512.0**	**34,500.0**	**66.6**	**1**	**0.1**	**7.00**	**0.05**	**53.2**	**48.0**	**7.6**	**4.0**	**8.5**	**20.2**	**15.1**	**14.4**	**233.0**	**143.0**	**26.2**	**12**	**0.29**	**0.35**	**0.028**
TGW Graywater	**0.080**	**138.00**	**228.0**	**369.0**	**17.1**	**1**	**10.0**	**8.19**	**16**	**0.3**	**0.5**	**0.6**	**0.9**	**84.7**	**173.0**	**1.8**	**2.6**	**0.6**	**1.2**	**86.9**	**60**	**9.00**	**2.80**	**14.00**
Min	0.080	0.05	228.0	369.0	17.1	1	0.1	6.88	0.05	0.3	0.5	0.6	0.9	8.5	20.2	1.8	2.6	0.6	1.2	26.2	12	0.29	0.35	0.28
Max	29.400	134.00	870.0	34,500.0	75.2	22	25	8.19	40	53.2	48.0	10.3	5.0	163.0	339.0	21.2	23.2	233.0	132.0	86.9	600	9.00	8.00	14.00
GeoMean	0.750	11.980	476.2	13,058.0	38.5	2	3.94	7.61	6.19	16.1	14.5	3.9	2.4	48.2	90.4	10.9	10.4	52.4	46.9	60.6	63.4	1.46	2.48	1.16

Table II-4: Small Ships – VOCs

2002 data (units of measure in µg/l)

	1,2,4-Trimethylbenzene	2-Butanone	4-Isopropyltoluene	Acetone	Benzene	Bromodichloromethane	Bromoform	Bromomethane	Carbon Disulfide	Chloroethane	Chloroform	Chloromethane	Dibromochloromethane	Iodomethane	m&p Xylenes	Naphthalene
MDL	**0.15**	**0.51**	**0.11**	**1.2**	**0.18**	**0.23**	**0.32**	**0.76**	**0.13**	**0.36**	**0.25**	**0.29**	**0.32**	**0.42**	**0.15**	**0.098**
Mixed BW&GW	9.9	0.255	.055	45	2.6	31	130	3.4	2.1	1.4	19	2.9	73	3.1	8	8.5
Mixed BW&GW	0.67	8.3	2.4	47	2	8.9	89	1	4.4	0.18	5.8	4.5	30	0.21	0.55	1.2
Mixed BW&GW	.075	0.255	0.055	4	0.09	0.135	36	0.38	0.065	0.18	0.125	0.15	1.1	0.21	0.075	0.05
Mixed BW&GW	.075	0.255	0.055	0.6	0.09	1.6	57	1.1	0.065	0.18	0.125	1.9	8.8	0.21	0.075	0.05
TBW Blackwater	0.075	0.255	0.055	9.1	0.09	0.135	0.12	0.38	1	0.18	0.125	0.15	0.16	0.21	0.075	0.05
TGW Graywater	0.075	5.9	0.055	52	0.09	7.2	0.12	0.38	0.065	1.3	140	2.7	1.7	0.21	0.075	0.05
Min	0.075	0.255	0.055	0.6	0.09	0.135	0.12	0.38	0.065	0.18	0.125	0.15	0.16	0.21	0.075	0.05
Max	9.9	8.3	2.4	52	2.6	31	130	3.4	4.4	1.4	140	4.5	73	3.1	8	8.5
GeoMean	0.244	0.769	0.069	8.44	0.264	1.87	9.2	0.768	0.369	0.352	1.76	1.07	4.04	0.33	0.228	0.197

Large Ships

Voluntary sampling of large ships began in 2000. The federal government had legislation in place for the entire 2001 cruise season. The State of Alaska had legislation regulating wastewater discharges as of July 1, 2001.

The 2000 and 2001 data were divided into several tables included in Appendix 6.

Table II-5 includes the geometric means of the individual tables to compare the treatment types, effluent types, and whether the wastewater was held for periods of time versus collected and discharged immediately.

The water from collecting tanks was sampled as it was discharged overboard or to a double bottom (ballast) holding tank. Samples from double bottom tanks can only be taken while the ship is discharging to ambient water. The wastewater was often stored in the double bottom tanks for up to 20 hours.

It appears that the fecal coliform counts are increasing as the wastewater incubates in the double bottom tanks. The fecal coliform geometric mean of all graywater types over 2000 and 2001 is 135,922 MPN /100ml from ballast and double bottom tanks compared with 515 MPN/100ml from collecting tanks. The TSS of graywater from double bottom tanks is 128.58 mg/l and 118 mg/l from collecting tanks.

The mixed treated blackwater and graywater (BW&GW) stored in double bottom tank had a fecal coliform geometric mean of 12,824 MPN/100ml and a TSS geometric mean of 119 mg/l.

The fecal coliform geometric mean of treated blackwater only that was sampled from the treatment system outlet is 18,213 MPN/100 ml with a TSS geometric mean of 478 mg/l. These results concluded that the blackwater treatment system was not functioning properly.

There are two reasons why the geometric mean of fecal coliforms results of the mixed BW&GW stored in the double bottom is lower than results from the blackwater treatment system. First, the blackwater system is blackwater only whereas the double bottom samples have graywater mixed with blackwater. Untreated blackwater should have higher fecal coliform counts than graywater. Secondly, the geometric mean from the double bottom tanks included two samples from advanced systems that had results below the detection limit for fecal coliforms. These two sample results lowered the geometric mean substantially for mixed treated blackwater and graywater.

The geometric mean of ammonia in 2000 for the treated blackwater (BW) was high, 104.48 mg/l.

Here is a summary of the 2000 and 2001 conventional pollutant geometric means:

Table II-5: 2000 Large ship summary data

Type of Water	**Samples**	**Sampled From Tank Type**	**Results as a geometric mean**				
	n		**Fecal Coliform (MPN/100 ml)**	**TSS mg/l**	**BOD mg/l**	**COD mg/l**	**Cl residualmg/l**
Galley	14	CT	13,750	420	728	1,317	0.05
Galley[18]	10	DB	784,072	512	1,587	2,404	0.05
Mixed GW	24	CT	118,052	124	223	573	0.06
Accommodations	3	CT	104	297	324	1340	0.05
Laundry	10	CT	8	38	74	340	0.2
Accomo.& Laundry	3	CT	6.13	77.5	63	240	0.13
Mixed BW&GW	11	DB	12,824	119	146	338	0.16
Blackwater[19]	22	MSD	18,213	478	105	845	0.21

2000 Graywater

- GW mixed in collecting tanks geometric mean is slightly acidic with a pH 6.62 and has COD geometric mean of 573 mg/l, and high fecal coliform geometric mean of 118,052 MPN/100ml.
- GW laundry in collecting tanks is relatively benign with a fecal coliform geometric mean of 8 MPN/100ml and TSS of 38 mg/l.

[18] Galley graywater is the highest source of fecal coliform. Some samples were taken from small tanks that have food wastes that raised the geometric mean. Galley graywater accounts for approximately 25% of graywater.

[19] Ammonia geometric mean is 104.48 mg/l.

- GW accommodations collecting tanks had three samples with missing parameters. The fecal coliform geometric mean is 104 MPN/100ml. One sample had a COD results of 1340 the other results had missing COD.

GW laundry and accommodation graywater had only three samples taken and has fecal coliform and TSS results of 6 MPN/100ml and 77.5 mg/l.

2000 Blackwater

TBW from biological treatment MSD has high ammonia of 104.5 mg/l, TSS and fecal coliform results are 478 mg/l and 18,213 MPN/100 ml. The MSDs were not treating wastewater as designed.

TBW&GW from double bottoms had high fecal coliform geometric mean of 12,824 MPN/100ml.

Table II-6: 2001 Large Ship Summary Data

Type of Water	**Samples**	**Sampled From Tank Type**	**Results as a geometric mean**				
	N		**Fecal Coliform (MPN/100 ml)**	**TSS mg/l**	**BOD**	**COD**	**Cl residual**
Accommodation	15	DB	10,896	77	266	573	0.15
Accommodation	15	CT	2,189	67	282	527	0.49
Galley	10	DB	784,072	512	1,587	2,404	0.23
Galley	23	CT	Missing	349	728	1,414	0.34
Mixed Graywater	4	DB	649,994	114	259	367	0.05
Mixed Graywater	13	CT	38,933	108	246	474	0.11
Laundry	7	DB	651,460	66	230	634	0.12
Laundry	2	CT	30	22	86	571	0.32
Mixed BW&GW	16	MSD	2	2.7	6.73	16.7	0.07

2001 Graywater

- GW from accommodations stored in double bottom tanks had high fecal coliform geometric mean of 10,896 MPU/100ml but the TSS geometric mean complied with the 150 mg/L standard at 77. Accommodation graywater stored in collecting tanks fecal coliform geometric mean is 2,189 MPN/100ml and a TSS of 67 mg/L. The chlorine residual of the collecting tanks was 0.49 mg/L compared with 0.15 mg/L in double bottom tanks.

- GW Galley from double bottom tanks had the highest fecal coliform geometric mean of 784,072 MPN/100ml, the lowest pH of 4.8, a COD of 2404 mg/L and

1,587 mg/L of BOD. 2001 GW Galley from collecting tanks COD geometric mean was 1,414 mg/L and the total chlorine was 2 mg/L and a residual of 0.34 mg/L.

- GW laundry in double bottom tanks had a fecal coliform geometric mean of 651,460 MPN/100 ml and 66 mg/L of TSS.

- GW laundry in collecting tanks had only two samples but both samples had fecal coliform of 30 mg/L, low TSS of 22 mg/L, and low levels of chlorine of 0.32 mg/L.

- GW mixed from double bottom tanks fecal coliform geometric mean was 649,994 MPN/100 ml with a TSS of 113.5 mg/L. The graywater mixed from collecting tanks fecal coliform geometric mean and TSS was 38,933 MPN/100 ml and 108 mg/L

2001 Blackwater

- BW&GW mixed had low geometric mean for fecal coliform and TSS because most of the results were from advanced systems. Treated blackwater was not discharged in Alaska waters, except for advance treatment units and one ship that used a macerator chlorinating system. One ship that discharged their blackwater outside Alaska water sampled their blackwater voluntarily.

Table II-7: Large Ships Conventional Pollutants Geometric Means

2000 and 2001 data

# Samples	All Data In table Appendix 6	Sample Date	Sample From	Waste Type	Ammonia	PH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
				Units	mg/l		mg/l	mg/l	mg/l	mg/l	MPN	Umhos/cm	mg/l
				MDL	0.16	0.10	1.0	3.4	0.1	0.1	2	1.0	0.1
22	Table C1	2000	MSD	Treated BW	104.48	7.18	104.6	845.0	478.0	0.2	18,213	not taken	0.1
11	Table C2	2000	Ballast Tanks	BW&GW	7.12	6.73	146.3	338.0	119.0	0.2	12,824	not taken	0.1
24	Table C3	2000	Collecting Tanks	GW	1.41	6.62	223.0	573.0	124.0	0.1	118,052	not taken	0.1
10	Table C4	2000	Collecting Tanks	GW laundry	0.382	7.72	73.6	340.0	38.0	0.2	8	not taken	0.1
3	Table C5	2000	Collecting Tanks	GW laundry/ Accommodation	5.239	6.99	63.3	240.0	77.5	0.4	6	not taken	0.1
11	Table C6	2000	Collecting Tanks	GW galley	1.547	6.43	728.0	1,317.0	420.0	0.2	13,750	not taken	0.2
3	Table C7	2000	Collecting Tanks	GW accommodation	6.567	8.38	324.0	1,340.0	297.0	0.3	104	not taken	0.1
15	Table C8	2001	Ballast tanks	GW accommodation	0.08	6.36	266.0	573.0	77.0	0.2	10,896	939.0	0.2
23	Table C10	2001	Collecting tanks	GW Galley	1.27	7.04	728.0	1,414.0	349.0	2.0	Not taken	904.0	0.3
10	Table C11	2001	Ballast tanks	GW Galley	0.14	4.80	1,587.0	2,404.0	512.0	0.1	784,072	1,008.0	0.2
4	Table C12	2001	Ballast tanks	GW mixed	0.09	6.14	259.0	367.0	113.5	0.1	649,994	1,220.0	0.1
7	Table C13	2001	Ballast tanks	GW laundry	0.62	7.56	230.0	634.0	66.0	0.2	651,460	545	0.1
2	Table C14	2001	Collecting tank	GW laundry	Not taken	8.36	86.0	571.0	22.0	0.3	30	2,510	0.3
13	Table C15	2001	Collecting tank	GW mixed	0.48	6.96	245.9	473.9	108.0	0.2	38,933	562.4	0.1
16	Table C16	2001	Treatment	GW&BW mixed	1.08	6.88	6.7	16.7	2.7	0.1	2	223	0.1

# Samples	All Data In table Appendix 6	Sample Date	Sample From	Waste Type	Ammonia	PH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
				Units	mg/l		mg/l	mg/l	mg/l	mg/l	MPN	Umhos/cm	mg/l
				MDL	0.16	0.10	1.0	3.4	0.1	0.1	2	1.0	0.1
				GeoMean	1.17	6.89	184.5	515.5	103.7	0.2	3,275	806.6	0.1
				GeoMean-ballast	0.34	6.25	326.0	641.1	128.6	0.1	135,921	890.7	0.1
				GeoMean-collecting	1.50	7.28	209.9	649.3	118.1	0.3	515.43	1,084.6	0.1

All priority pollutant results with at minimum one result over the MDL, taken in 2000 and 2001 can be found in the tables C1-C33 in Appendix 6.

The listing of priority pollutants sampled is included in Appendix 4. These tables include total recoverable metals only.

Table II-8 includes the priority pollutants that had results in most samples or had high results for a few graywater samples.

All 2001 sample sets contained:

- bis (2ethylhexyl)phthalate
- Bromoform
- Chloroform
- Copper
- Lead
- Nickel
- Selenium
- Zinc.

Some of the 2001 samples contained:

- Butylbenzyl phthalate
- Diethylphthalate
- Chromium

In 2001, graywater from accommodations had elevated levels of chloroethane whereas the other samples had non-detection limits. These results can be found in Appendix 6, Table C17. One galley sample in 2001 had elevated levels of 2,4 dichlorophenol and 2,4,6 trichlorophenol compared to the rest of the sample set. These results can be found in Appendix 6, Table C18. All samples contained metals. These results are listed in Appendix 6, Table C19.

Appendix 6, Tables C17-20 have all off the priority pollutants with results over the detection limit. The following pollutants were detected in some of the results but non-detected in a majority of the results:

- Chloroethane (accommodations)
- Tetrachloroethane (mixed and BW)
- Trichloroethane (mixed)
- 2,4 dichlorophenol (galley)
- 2,4,6 trichlorophenol (galley)
- methylene chloride (accommodations)
- Ethyl benzene (accommodations & galley and 2000 laundry)
- Di-n-butylphthalate (accommodations & galley)

Table II-8: 2001 Large Ships Priority Pollutants for Graywater

(All units of measure in µg/l unless noted)

Tank Type	Water type	Sample Date	COD mg/l	total CL mg/l	bis(2-ethylhexyl) phthalate	Butylbenzyl phthalate	Diethylphthalate	bromoform	Chloroform	Chromium (TR)	copper (TR)	Lead (TR)	nickel (TR)	Selenium (TR)	zinc (TR)
		MDL	**3.4**	**0.1**	**0.69**	**0.38**	**0.55**	**0.32**	**0.25**	**2.3**	**1.2**	**1.4**	**1.1**	**4.8**	**2.8**
CT	Accomo	19-Sep-01	765.0	5.0	8.20	0.19	9.40	0.16	170.00	2.7	255.0	4.5	27.9	1.0	458.0
CT	Galley	19-Sep-01	642.0	10.0	9.10	1.40	6.90	0.16	0.13	10.6	74.9	2.5	15.4	0.9	173.0
CT	Mixed Gray	17-Aug-01	722.0	0.1	55.00	0.19	7.90	0.16	19.00	4.1	275.0	78.6	51.9	9.1	10,300
CT	Mixed Gray	17-Aug-01	520.0	0.1	15.00	0.19	7.40	1.40	19.00	4.9	272.0	12.6	56.0	6.6	1,390.0
DB	Mixed Gray	29-Aug-01	NA	NA	15.00	0.19	17.00	6.30	12.00	1.2	0.6	0.7	0.6	2.4	1.4
DB	Mixed Gray	29-Aug-01	NA	NA	21.00	0.19	20.00	6.50	8.90	1.2	0.6	0.7	0.6	2.4	1.4
DB	Mixed Gray	29-Aug-01	NA	0.1	0.35	0.19	0.28	0.16	0.13	1.8	338.0	1.7	15.00	0.6	289.0
DB	Mixed Gray	29-Aug-01	289.0	0.1	0.35	0.19	0.28	0.16	0.13	3.1	267.0	2.3	13.7	0.8	228.0
DB	Galley	02-Aug-01	1,620.0	0.5	3.40	0.19	7.60	0.16	140.00	10.7	652.0	1.1	17.1	1.2	106.0
DB	Galley	22-Aug-01	3,950.0	0.1	3.10	2.70	3.60	0.16	37.00	8.8	69.3	2.7	13.2	1.3	206.0
DB	Galley	23-Jul-01	1,290.0	0.1	5.80	1.90	6.30	31.00	16.00	13.6	1,710.0	94.7	32.3	31.5	400.0
DB	Acc/galley	26-Jul-01	521.0	NA	14.00	0.19	12.00	0.16	95.00	3.9	170.0	5.7	16.9	1.3	411.0

Tank Type	Water type	Sample Date	COD mg/l	total CL mg/l	bis(2-ethylhexyl) phthalate	Butylbenzyl phthalate	Diethylphthalate	bromoform	Chloroform	Chromium (TR)	copper (TR)	Lead (TR)	nickel (TR)	Selenium (TR)	zinc (TR)
		MDL	**3.4**	**0.1**	**0.69**	**0.38**	**0.55**	**0.32**	**0.25**	**2.3**	**1.2**	**1.4**	**1.1**	**4.8**	**2.8**
DB	Laundry	26-Jul-01	268.0	0.2	17.00	0.19	15.00	0.16	31.00	2.1	44.1	3.3	5.3	0.4	163.0
DB	Accomo	23-Jul-01	765.0	0.1	8.90	2.30	9.60	3.00	58.00	5.0	174.0	4.3	10.7	9.0	270.0
DB	Accomo	02-Aug-01	295.0	3.5	5.20	0.19	13.00	0.16	0.13	2.6	355.0	2.8	8.7	1.8	276.0
		Min	3.4	0.1	0.35	0.19	0.28	0.16	0.13	1.2	0.6	0.7	0.6	0.4	1.4
		Max	3,950.0	10.0	55.00	2.70	20	31.00	170.00	13.6	1,710.0	94.7	56.0	31.5	10,300.0
		GeoMean	700.1	0.2	6.51	0.36	5.913	0.52	7.77	3.8	103.4	4.0	11.1	2.0	179.3

Table II-9: 2001 Large Ships Priority Pollutants for Blackwater (includes GW&BW mixed)

All units of measure in µg/l unless noted.

Type	Water type	Sample Date	Chloroform	Bromoform	bis(2-ethylhexyl)phthalate	Arsenic III	Copper (TR)	Lead (TR)	Nickel (TR)	Selenium (TR)	Zinc (TR)
		MDL	**0.19**	**0.32**	**0.38**	**0.2**	**1.4**	**1.1**	**4.8**	**0.93**	**0.33**
Advanced	Mixed BW&GW	20-Sep-01	4.20	0.16	0.19	1.1	2.7	0.1	18.3	1.05	32.40
Advanced	Mixed BW&GW	09-Sep-01	11.00	0.16	4.20	0.1	0.5	0.2	0.7	0.21	3.02
Macerator	Mixed BW&GW	08-Aug-01	22.00	26.00	0.19	32.8	203.0	3. 7	25.4	105.00	228.00
Macerator	Mixed BW&GW	08-Aug-01	27.00	13.00	3.10	36.0	98.7	0.6	22.7	155.00	111.00
No treatment/DB	Mixed BW&GW	19-Aug-01	1.70	0.16	7.00	53.4	169.0	3.4	16.2	152.00	268.00
Biological	BW	19-Aug-01	0.87	0.16	0.19	9.0	1,670.0	80.3	38.1	8.31	3,020.00
		Min	0.87	0.16	0.19	0.1	0.5	0.1	0.7	0.21	3.02
		Max	27.00	26.00	7.00	53.4	1,670.0	80.3	38.1	155.00	3,020.00
		GeoMean	5.86	0.78	0.93	6.3	44.3	1.4	12.8	12.89	112.29

Table II-10 includes the priority pollutants that had results in most samples or had high results for a few graywater samples.

Some of the 2000 graywater sample sets contained:

- bis (2ethylhexyl)phthalate
- Diethylphthalate
- Chloroform
- Copper
- Lead
- Nickel
- Zinc

Appendix 5, Tables C26-C33 have all off the priority pollutants with results over the minimum detection limit (MDL).

Some of the 2000 blackwater samples contained the following priority pollutants:

- bis(2-ethyl hexyl) phthalate
- Bromodichloromethane
- Chloroform
- chromium (TR)
- Copper (TR)
- Cyanide (total)
- Dibromochloromethane
- di-n-butyl phthalate
- Lead (TR)
- Methyl Chloride
- Phenol
- Zinc
- Bromoform

Table II-10: 2000 Large Ship Priority Pollutants for Graywater

All units of measure in µg/l unless noted.

	bis(2-ethyl hexyl)phthalate	Diethy lphthalate	di-n-butyl phthalate	Chlor oform	copper (TR)	Lead (TR)	Nickel (TR)	Zinc(TR)
MDL	**0.38**	**0.55**	**1.40**	**0.25**	**1.20**	**1.40**	**1.10**	**2.80**
Ballast tank 5S	17.00	3.70	2.50	15.00	150.00	0.70	46.00	460.00
composite graywater	10.00	3.00	1.10	0.13	260.00	7.50	0.55	560.00
Composite# 4,6,11	11.00	0.28	0.70	0.13	2200.00	0.70	0.55	860.00
Gray water accumulation tank 4	0.19	0.28	0.70	4.00	0.60	0.70	0.55	1.40
Gray water composite Mixed	0.19	1.10	6.50	0.13	230.00	21.00	0.55	480.00
Gray water galley tank 4	0.19	0.28	0.70	2.00	0.60	0.70	0.55	1.40
Gray water overboard	32.00	0.28	0.70	1.80	62.00	2.50	0.55	350.00
graywater composite	15.00	5.80	8.40	0.13	1203.40	21.40	99.00	770.00
graywater port	0.19	0.28	0.70	15.00	0.60	0.70	0.55	1.40
graywater starboard	0.19	0.28	0.70	19.00	0.60	0.70	0.55	1.40
Gry 78 port	20.00	4.50	2.20	44.00	180.00	0.70	0.55	750.00
Gry accom	0.19	0.28	0.70	313.00	0.60	0.70	0.55	1.40
Gry ballast #6	0.19	0.28	0.70	4.10	0.60	0.70	0.55	1.40
Gry comp	183.00	13.00	8.10	0.13	4320.00	387.00	184.00	2860.00
Gry composite	112.00	12.80	10.30	0.13	710.00	28.00	676.00	1460.00
Gry DHTS composite	35.00	6.00	5.30	0.13	720.00	0.70	46.00	600.00
Gry gal/acco	0.19	0.28	0.70	19.00	0.60	0.70	0.55	1.40
Gry galley	0.19	0.28	0.70	292.80	0.60	0.70	0.55	1.40
Gry galley #11	0.19	5.80	0.70	1.40	0.60	0.70	0.55	1.40
Gry galley tank #11	3.70	6.30	3.30	48.00	650.00	62.00	0.55	530.00
Gry galley tank H	0.19	0.28	0.70	14.00	0.60	0.70	0.55	1.40
Gry HTS composite	51.00	8.50	6.80	0.13	830.00	0.70	44.00	400.00
Gry laundry	0.19	0.28	0.70	207.00	0.60	0.70	0.55	1.40

	bis(2-ethyl hexyl)phthalate	Diethy lphthalate	di-n-butyl phthalate	Chlor oform	copper (TR)	Lead (TR)	Nickel (TR)	Zinc(TR)
MDL	**0.38**	**0.55**	**1.40**	**0.25**	**1.20**	**1.40**	**1.10**	**2.80**
Gry pump accom.	0.19	0.28	0.70	2.30	0.60	0.70	0.55	1.40
Gry tank #2	20.00	5.80	2.10	1.80	130.00	0.70	85.00	340.00
Gry tank 3C	7.60	3.60	3.30	26.00	1500.00	0.70	140.00	540.00
Gry tank 7 port and starboard	14.00	11.00	3.00	16.00	150.00	0.70	0.55	740.00
Gry tank C	0.19	0.28	0.70	15.00	0.60	0.70	0.55	1.40
Gry Tank F	13.00	15.00	1.60	6.50	210.00	0.70	0.55	330.00
Grywtr 5 tank (composite)	19.00	9.70	0.70	0.13	480.00	14.00	0.55	1.40
Grywtr laundry room	0.19	0.28	0.70	13.00	0.60	0.70	0.55	1.40
Grywtr shaft tank	0.19	0.28	0.70	34.00	0.60	0.70	0.55	1.40
Grywtr stabilizer port tank	0.19	0.28	0.70	25.00	0.60	0.70	0.55	1.40
Main graywater	0.19	0.28	0.70	15.00	0.60	0.70	0.55	1.40
Starboard graywater	0.19	0.28	0.70	96.00	0.60	0.70	0.55	1.40
Min	0.19	0.275	0.7	0.125	0.6	0.7	0.55	1.4
Max	183	15	10.3	313	4320	387	676	2860
GeoMean	1.56	1.11	1.37	4.19	13.82	1.55	1.80	21.45

Table II-11: 2000 Priority Pollutants for Blackwater

All units of measure in µg/l unless noted.

Samples from	Bis(2-ethyl hexyl) phthalate	Bromodichlo romethane	Chloro	Chromium (TR)	Copper (TR)	Cyanide (total)	Dibromochlo romethane	di-n-butyl phthalate	Lead (TR)	Methyl Chloride	Phenol	Zinc (TR)	Bromoform
MDL	**0.38**	**0.46**	**0.25**	**2.3**	**1.2**	**1.6**	**0.32**	**1.4**	**1.4**	**1.2**	**0.85**	**2.8**	**0.32**
DB	0.19	0.23	0.13	3.1	0.6	0.8	0.16	0.7	0.7	0.6	0.43	1.4	0.16
Double bottom	1.50	0.23	0.79	1.7	510.0	0.8	0.16	0.7	30.0	0.6	250.00	1200.0	0.16
	17.00	1.10	15.00	1.7	150.0	0.8	0.16	2.5	0.7	0.6	0.43	460.0	0.16
	6.50	6.30	6.70	1.7	530.0	0.8	0.16	3.9	0.7	0.6	0.43	530.0	16.00
	3.70	0.23	0.13	10.0	3900.0	0.8	0.99	8.2	0.7	0.6	160.00	390.0	0.16
HT holding	8.80	1.70	13.00	1.7	6400.0	0.8	0.16	2.1	16.0	0.6	2.10	1800.0	1.10
MSD	1.90	0.23	0.13	1.7	360.0	0.8	0.16	0.7	0.7	0.6	0.76	170.0	0.16
	2.00	0.23	2.90	1.7	210.0	0.8	0.16	0.7	0.7	0.6	0.59	390.0	3.30
	1.90	1.90	1.60	1.7	50.0	0.8	1.4	4.8	0.7	0.6	0.27	210.0	1.20
	0.19	18.00	21.00	18.0	560.0	25.0	40	0.7	23.0	25.0	0.43	1100.0	95.00
	0.19	1.10	18.00	1.5	150.0	51.0	0.16	0.7	1.8	0.6	0.18	350.0	0.16
	0.19	18.00	20.00	1.7	530.0	19.0	18	0.7	27.0	0.6	1.90	1000.0	28.00
	0.19	77.00	210.00	1.7	240.0	73.0	88	0.7	0.7	0.6	0.43	580.0	170.00
	1.40	110.00	140.00	1.7	170.0	0.8	63	3.2	18.0	9.4	1.50	800.0	14.00
	2.30	43.00	200.00	1.7	760.0	0.8	16	2.0	0.7	0.6	0.43	1.4	6.10
	6.20	180.00	380.00	14.0	7100.0	28.0	270	2.7	0.7	160.0	2.00	610.0	440.00
	5.10	53.00	93.00	19.0	360.0	26.0	56	3.1	0.7	0.6	0.43	620.0	80.00
	0.19	0.23	1.60	25.0	130.0	0.8	0.16	2.6	0.7	0.6	0.43	700.0	0.16
	0.19	190.00	1500.00	1.7	0.6	0.8	88	0.7	0.7	81.0	0.43	1.4	25.00
	1.80	0.23	3.70	1.7	54.0	0.8	0.16	2.1	0.7	240.0	0.43	250.0	0.16

Samples from	Bis(2-ethyl hexyl) phthalate	Bromodichlo romethane	Chloro	Chromium (TR)	Copper (TR)	Cyanide (total)	Dibromochlo romethane	di-n-butyl phthalate	Lead (TR)	Methyl Chloride	Phenol	Zinc (TR)	Bromoform
MDL	**0.38**	**0.46**	**0.25**	**2.3**	**1.2**	**1.6**	**0.32**	**1.4**	**1.4**	**1.2**	**0.85**	**2.8**	**0.32**
Overboard	0.19	0.23	1.20	1.7	0.6	0.8	0.16	0.7	0.7	0.6	0.43	1.4	0.16
	3.60	3.60	15.00	52.0	740.0	0.8	13	9.8	50.0	0.6	1.90	140.0	30.00
Reverse	4.10	0.23	4.80	1.7	0.6	0.8	0.16	0.7	0.7	0.6	0.43	7.0	0.16
Osmosis	1.30	0.23	4.10	1.7	0.6	0.8	0.16	1.1	0.7	0.6	0.43	1.4	0.16
Min	0.19	0.23	0.13	1.5	0.6	0.8	0.16	0.7	0.7	0.6	0.18	1.4	0.16
Max	17.00	190.00	1500.00	52.0	7100.0	73.0	270.00	9.8	50.0	240.0	250.00	1800.0	440.00
GeoMean	1.25	2.58	8.84	3.1	107.3	2.0	1.59	1.6	1.8	1.6	0.96	124.1	2.17

Priority Pollutant Conclusions

A majority of priority pollutant results are below the minimum detection limit.

Out of the 55 priority pollutant categories sampled, graywater and blackwater contains only 16 pollutants, sometimes in trace amounts. The geometric means of the results are in Table II-12.

Table II-12: Geometric mean Summaries of Priority Pollutants

in parts per billion (ppb) or micrograms per liter (µg/L)

ANALYTE	MDL	GW 2001	BW 2001	GW 2000	BW 2000
Bis (2ethylhexyl) phthalate	0.38	6.51	0.93	1.56	1.25
Bromoform	0.32	0.52	0.78	ND	2.17
Chloroform	0.25	7.77	5.86	4.19	8.84
Cyanide	1.6	ND	ND	ND	2
Butylbenzyl phthalate	0.38	0.36	ND	ND	ND
Diethylphthalate	0.55	5.91	ND	1.11	ND
Bromodichloromethane	0.46	ND	ND	ND	2.58
Dibromochloromethane	0.32	ND	ND	ND	1.59
di-n-butyl phthalate	1.4	ND	ND	1.37	1.6
Methyl Chloride	1.2	ND	ND	ND	1.6
Phenol	0.85	ND	ND	ND	0.96
Chromium	2.3	3.8	ND	13.82	3.1
Copper	1.2	103.4	44.3	1.55	107.3
Lead	1.4	4.0	1.4	1.8	1.8
Nickel	1.1	11.1	12.8	ND	ND
Selenium	4.8	2.0	12.89	ND	ND
Zinc	2.8	179.3	112.29	21.45	124.1

No heavy metals such as cadmium and mercury were detected. There were no PCBs or pesticides detected in the sampling data. Chloroform is present in most samples of blackwater and graywater. Copper and zinc are metals of most concern. The addendum with the full 2002 analysis will provide a fuller analysis of these pollutants.

Section III

An Assessment of Fecal Coliform Bacteria in Cruise Ship Wastewater Discharge

Charles McGee, Lincoln Loehr, and Kenwyn George

Summary

The Science Advisory Panel evaluated environmental and public health impacts of the discharge of wastewater from cruise ships in Alaska. This section focuses on fecal coliform bacteria. The functional definition of fecal coliform is those coliform that will produce gas from lactose in a liquid medium within 24 ± 2 hours at 44.5 ± 0.2 °C. Scientifically, the fecal coliform group includes the subset of total coliform bacteria from the genera *Escherichia,* and *Klebsiella*. Other genera in the total coliform group are *Citrobacter* and *Enterobacter*. *Escherichia coli* is the most predominant member of the fecal coliform group [Eaton et al. 1995]. Historically, fecal coliform have been used to indicate the presence of sewage in environmental waters and as an index of the sanitary quality of the water. Fecal coliform, as a group, are not necessarily responsible for illness but because they are always found in the intestinal tract of humans and other warm-blooded animals (including birds) their presence indicates the potential for exposure to other pathogenic microorganisms that are shed from the gastrointestinal tract.

This section discusses fecal coliform standards in Alaska, examines data on the levels of fecal coliform present in cruise ship discharges in the context of the standards, the fate of fecal coliform following discharge into marine waters, and the impact the discharges might have on public health. The relevant scenarios of exposure include secondary contact recreation by fishermen, kayakers and motor-powered watercraft crossing a cruise ship wake shortly after passage of the cruise ship, and raw shellfish consumers harvesting shellfish along the shoreline. The available data, coupled with the relevant dilutions, indicate that violations of the applicable bacterial water quality standards are not predicted to occur for any of these scenarios.

Alaska's Fecal Coliform Water Quality Standards

Water quality standards for bacteria are established to protect humans from gastrointestinal illnesses caused by fecal pathogens, and vary based on designated uses of the water. However, unless a water body has been classified such that a particular standard is not applicable or has been modified for particular uses, the most stringent criteria will apply. For the purposes of this paper, the Panel considered and reports on those uses most likely to occur and be affected at particular locations. For example, contact recreation is feasible at sea, whereas the collection of mollusks and other aquatic life for raw consumption only occurs along the shoreline. Alaska's designated usages and the standards associated with those usages are stated in Alaska State Regulation 18 AAC 70.020 and are listed below:

Aquaculture

For products normally cooked,

200 fecal coliform (FC)/100 ml as a geometric mean[20] for samples over a 30-day period with no more than 10% of the samples exceeding 400 FC/100 ml.

For products not normally cooked,

20 FC/100 ml as a geometric mean for samples over a 30-day period with no more than 10% of the samples exceeding 40 FC/100 ml.

Seafood processing

20 FC/100 ml as a geometric mean for samples over a 30-day period with no more than 10% of the samples exceeding 40 FC/100 ml.

Industrial uses

200 FC/100 ml as a geometric mean for samples over a 30-day period with no more than 10% of the samples exceeding 400 FC/100 ml.

Contact recreation[21]

100 FC/100 ml as a geometric mean for samples over a 30-day period with no more than 10% of the samples exceeding 200 FC/100 ml.

Secondary recreation[22]

200 FC/100 ml as a geometric mean for samples over a 30-day period with no more than 10% of the samples exceeding 400 FC/100 ml.

Harvesting of raw mollusks or other raw aquatic life for human consumption

Based on a 5-tube decimal dilution test, the median[23] MPN may not exceed 14 FC/100 ml, and not more than 10% of the samples may exceed a median MPN of 43 FC/100 ml.

The standard for consumption of raw mollusks or other raw aquatic life is derived from the National Shellfish Sanitation Program (NSSP) requirements promulgated by the Food and Drug Administration (FDA). The NSSP is a cooperative State-FDA-Industry

[20] "geometric mean" means the *n*th root of the product of a series of n numbers;. eg. (2 x 9 x 5) ^1/3 = 4.48

[21] "contact recreation" means activities in which there is direct and intimate contact with water, including wading, swimming, diving, water skiing, and any intimate contact with water directly related to shoreline activities.

[22] "secondary recreation" means recreation activities in which water use is incidental, accidental, or sensory, including fishing, boating, camping, hunting, and hiking..

[23] "median" means the value in a data set that splits a data set in half, such that have of the reported values are above the median and half are below.

program for the certification of shellfish beds for commercial harvest. The NSSP standards say that either the geometric mean or the median can be used.

Alaska's Fecal Coliform Effluent Standards for Commercial Passenger Vessels

Effluent standards were recently adopted for commercial passenger vessels in Alaska. Effluent standards are not to be confused with water quality standards. Rather, they are performance standards that the wastewater treatment technologies employed are required to attain. Unlike water quality standards, effluent standards do not allow consideration of dilution in implementation nor do they have any relation to the uses and exposure scenarios in Alaska's water quality standards.

Federal[24] and State of Alaska standards[25] for Large Commercial Passenger Vessels (overnight accommodations for 250 or more passengers)

200 FC/100 ml graywater and treated blackwater discharged from vessels traveling at 6 knots and at least one nautical mile from the nearest shore.

If the effluent meets the most stringent standards under Coast Guard regulations), the vessel may discharge at less than 6 knots and within 1 mile of the shoreline if fecal coliform does not to exceed 20/100 ml (30-day geometric mean) [26].

State of Alaska[7] standards for Small Commercial Passenger Vessels (accommodations for between 50 and 249 passengers)

200 FC/100 ml for graywater and treated blackwater. These standards will be effective January 1, 2004.[27]

Alaska's bacteria standards are composed of limits based on geometric means or medians and frequencies of events where the single sample concentration exceeds a level of concern. Implicit in all these standards is that multiple measurements are made over time. Such an approach is necessary to overcome the challenges presented by trying to assess water quality based on bacteria measurements.

Dealing with Highly Variable Fecal Coliform Data Sets

Monitoring fecal coliform in the environment generates data sets with specific challenges. These include significant temporal variability, large ranges in values that affect data distribution, and the fact that the results of monitoring are always generated after the exposure to the public has occurred. All these are thus underlying reasons for standards based on geometric means, medians or frequencies of occurrences.

[24] 33 CFR 159 Subpart E
[25] Alaska Statute 46.03.460 (b) & (c)
[26] 33 CFR 159.309 (b)
[27] Alaska Statute 46.03.460 – 490, uncodified Section 7.

Climate, rain runoff, and fecal deposits from indigenous animal populations can result in changes of fecal coliform concentrations in surface waters every few minutes. This means that two samples collected several minutes apart could potentially have fecal coliform levels that differ by orders of magnitude. A perfectly designed monitoring program would capture this temporal variability by collecting and analyzing samples at a frequency equal to the variability interval, which is minutes. Cost and logistics prohibit such a monitoring program, and it is not atypical for regulators and public health officials to make an evaluation of water quality based on results from one sample per week.

In addition to temporal variability, bacterial measurements are also subject to extreme ranges. It is possible for the data set to have fecal coliform concentrations at or below the detection limit, which could be one organism per 100 milliliters (ml), to concentrations in the millions per 100 ml.

A mathematical approach for dealing with a highly variable population is to make multiple measurements over time and base decisions on statistical summaries of the data set. Measures of central tendency estimate the center of the data distribution and examples of those measures include mean, median and mode. The mean statistic is the average of individual measurements and is very commonly used with environmental data [Thomas, 1955]. As multiple measurements are made over time, an historical record develops and the mean represents the center of the frequency distribution of those measurements.

However, a fecal coliform historical record poses its own challenges to calculating a mean. When factors affecting variability of the measurements are few, small in effect, random in occurrence, and act in a simple additive fashion then the distribution of the variations follow what is called a Gaussian or a normal distribution curve, and measures of central tendency are relatively reliable. As mentioned above, such is not the case with bacteria measurements. Bacteria monitoring data do not typically have a normal distribution and this translates into a high level of uncertainty with regard to statistical estimation and inference [Shumway and Azari, 1988; Parkin, 1990].

One mathematical approach to dealing with data records that are non-normal is to use a process that transforms the individual measurements into a data set that better fits into a normal distribution. The method often applied to environmental data that accomplishes this is to transform the values to their logarithm, perform the analyses and then transform the data back to its original form. This method is less likely to be skewed by extreme values than the calculation of a mean. In so doing, decision-making is somewhat more mathematically sound, and it is for this reason many of Alaska's standards are based on a geometric mean.

Alaska's shellfish harvesting standard is based on a median value. The median is also a descriptive statistic of central tendency of the data. The value is the value that splits a data set so that half of the individual measurements are below the median value and half are above. The median is calculated by sorting the measurements numerically and determining the mid value. In the case where the data set contains an even number of measurements the two mid values are averaged. The advantage of a median is that it is

not as susceptible to the extreme values and it is especially useful in data sets with skewed frequency distributions, which are common in microbiological data [Hurst, et al, 2002]. Medians are also useful when considering health risk from exposure to fecal contamination. Consider a data record where all measurements of fecal coliform except one were below the minimum detection limit, which could be one organism per 100 mL. The other sample contained one million organisms per 100 mL. The majority of people recreating at this location were not exposed to any additional risk of gastrointestinal illness. However, those recreating on the day when high fecal coliform were measured were exposed to significant risk. At no time were all the people recreating in this area over the multiple days when samples were collected exposed to an average concentration of fecal coliform per 100 mL.

Another advantage of standards based on measurements made over time is that a regulator or public health official does not have real time information upon which to base decisions. Results of analyses for fecal coliform take a minimum of one day and with one method as long as 96 hours to become final. As a result, long-term trends are very important in decision-making.

Fecal Coliform and Cruise Ships

Fecal coliform discharges from cruise ships were considered in the context of Alaska's standards in order to identify and address those situations that pose real water quality concerns. An understanding of this issue could then help to determine if mitigation alternatives are needed and which method might be most effective. Mitigation alternatives could vary from 1) mandating a technology based level of treatment, 2) requiring the use of best management practices (including strategies to optimize mixing rates), or 3) establishing specific discharge limits and allowing industry the latitude as to how to achieve the limits.

During the summer of 2000, data from 21 large cruise ships were collected. More limited monitoring occurred in 2001. Although some of these cruise ships did not participate in data collection in subsequent years[28] the 2000 data provide a useful basis for establishing typical discharge concentrations and a comparison to bacteria standards. A typical practice for cruise ships is to separate toilet waste (blackwater) from other wastewaters such as shower or galley water (graywater). While blackwater may pose a greater risk to public health than graywater, there is no consideration of sources of fecal coliform in water quality standards. In 2000, graywater samples often had fecal coliform counts that were as high as blackwater. As a result separation of the two discharges in this discussion in terms of impact on standards is not justified.

In the 2000 monitoring season, 94 black, 81 gray and 11 combined black and gray water samples were analyzed. The geometric mean of these data was 5,460 FC/100 mL, the median was 27,500 FC/100 mL and the range of values was from <2 to >16,000,000 as

[28] As problems with traditional treatment technology for wastewater on large cruise ships became apparent, several vessels elected not to discharge wastewater in Alaska in 2001. Raw sewage and other wastewater exceeding Alaska effluent limits can be legally discharged at certain distances offshore.

determined by the multiple tube fermentation technique. Discharges were only allowed when the ships were underway. Although 11 large ships were monitored in 2001, the data were similar.

Dilution of Wastewater Behind a Moving Cruise Ship

Discharge of wastewater from a moving ship provides real benefit when considering the influence of the discharge on compliance with the water quality standards in the receiving waters. The discharge from a fixed-point municipal sewage outfall relies on treatment to a certain level followed by dilution and dispersion of the discharge to mitigate potential environmental impact. As the ship moves through the water the discharge is spread over a larger area than from a static point source, the hull displaces large amounts of water that fill in behind the ship, and the propellers assist in mixing the discharge into the surrounding water. Thus, the concentration of fecal coliform and other constituents in the water behind the ship is directly influenced by ship speed and discharge rates. Ultimately, additional dispersion, dilution, coliform die-off rates, sinking of particulates, currents and winds further diminish the fecal coliform concentrations associated with releases from a large moving cruise ship.

Section I of this report discusses dilution factors behind ships in detail. The findings from that section state that a reasonable dilution of wastewater of 1:50,000 would be achieved within minutes from a large cruise ship traveling at a minimum speed of six knots and discharging up to 200 cubic meters per hour of wastewater. It is also expected that an additional dilution of 1:100 would be achieved by the time that the discharge travels laterally one nautical mile, the minimum distance from shore that discharge is permitted under State and Federal regulations. Appendix 7 shows fecal coliform monitoring data from the 2000 and 2001 summer sampling and depicts levels of fecal coliform both behind the ship and one nautical mile laterally from the ship. Dilutions will be greater for discharges at higher speeds, lesser rates of discharge, or greater distances from shore. The appendix shows the bacteria levels for each measured discharge following dilution factors of 50,000 (the minimal initial dilution), 500,000 (an intermediate dilution) and 5,000,000 (a minimal dilution by the time any effluent approaches the nearest shore based on a combination of the 50,000 and 100 dilution factors). The end of the appendix shows the geometric mean, the median, and the percent exceedances above specific levels of regulatory concern in Alaska's water quality standards for the data set following these dilutions.

Potential Exposure for Individual Waterway Users

Because of the nearly immediate dilution behind a large cruise ship, it would be difficult for an individual to attain any significant exposure to the discharge. The only "significant exposure" scenario envisioned would be an individual on a powered watercraft such as a jet ski following behind the ship. Sea kayaker exposure in this zone would be brief unless the kayaker's track was along or close to the path of the cruise ship. The Alaska water quality standard that would apply to this dilution zone would be secondary recreation, one where exposure is incidental with only minimal or no ingestion

of water expected. The secondary recreation standard is based on the geometric mean of the data set. With a standard of 200 fecal coliform/100 ml, and a minimum dilution behind a cruise ship of 50,000, then, from the data set, the effluent geometric mean would have to be greater than 10,000,000 fecal coliform/100 ml to be in violation of the standard. For the 10% requirement of the standard to be exceeded, more than 10% of the samples collected over a 30-day period would have to have a concentration of 20,000,000 fecal coliform/100 ml in the effluent. Such a scenario would be unlikely as demonstrated by the data from the summers of 2000 and 2001.

Fate of Fecal Coliform Discharged into the Environment

In addition to the effects of dispersion and dilution, bacteria discharged into the environment begin to die off. Fecal coliform bacteria are best adapted to living in a warm, dark, isomotic, balanced pH environment with an abundance of food. Following discharge into marine waters, bacteria levels begin to decline due to environmental factors such as salinity, heavy metals, coagulation and flocculation, nutrient deficiencies, predation, bacteriophages, algae and bacterial toxins.[Hurst et al 2002]. Hurst et al (2002) have also shown that because microbes have an intrinsic electrostatic charge they adsorb to the surface of charged environmental particulates or the air-water interface, the micro layer, by hydrophobic mechanisms where they become subject to sedimentation or solar radiation. Various combinations of, and fluctuations in these environmental factors do not allow us to apply a consistent rate of bacteria reduction. However because these environmental phenomena are occurring, they provide a confidence that the number of fecal coliform reaching the shore under our analysis errs on the conservative side. Doubtlessly, fewer bacteria reach the shore than the tables calculate.

Numerous studies have been conducted examining the die-off rates of *E. coli,* the largest member of the fecal coliform group, in water. Of all the factors affecting survival or die-off, the most important ones appear to be temperature and solar radiation, with cooler temperatures and low solar radiation the most conducive to survival. Light is not as significant a factor in extremely turbid waters or once coliform bacteria are deposited in the sediment. It is not clear however, whether light only makes the organisms more susceptible to inactivation by any of the other factors [Chamberlain, and Mitchell, 1993]. Because of the interaction of multiple factors and geographic differences in these factors, there is no single die-off rate that can be universally applied to bacteria die-off. In general however, the literature supports a time range for 90% of the *E. coli* to die off (T_{90}) to be as short as four to six hours to several days [Chamberlain, et al 1993]. Solar radiation during the early and latter parts of the Alaska cruise ship season should be similar to those at lower latitudes and the water temperature is cool. One could assume therefore, that bacterial survival during the cruise season should be similar to that described by Chamberlain.

Cruise Ship Discharges in Context

Cruise ship discharges should also be considered within the context of a background of fecal coliform from all land-based sources. The number of fecal coliform excreted by

warm-blooded animals, including humans, ranges from 10^9 to 10^{10} organisms per gram of feces [Eaton et al. 1995]. Alderisio and DeLuca (1999) demonstrated that gull feces contained about 3.68 X 10^8 bacteria per gram and that goose feces contain about 1.53 X 10^4 bacteria per gram, and that the volume of geese waste was typically 15 times that of the gull. Fecal coliform densities in storm runoff in southern California are typically in the tens of thousands per 100 ml [OCSD, 1989]. Communities in Alaska where homes are on septic systems and are clustered along the shoreline present the opportunity for high fecal discharges, especially where the septic systems fail, which frequently happens in the rocky Alaskan coastal environment. Runoff from snowmelt and rainfall will contain fecal coliform from indigenous land animals as well as pets. Waters adjacent to marine mammal haul-out areas will also contain elevated fecal coliform levels. These background sources of fecal coliform complicate the water quality picture and in many cases result in fecal coliform concentrations higher at the shoreline than offshore.

Calculations of dilutions set a distance of one mile off the ship's track, may be used to represent where remnants of any discharge might reach shore if a vessel stayed just one mile from shore when discharging. This assumes oceanographic conditions that allow a shoreward transport of surface water. As previously discussed, an additional dilution factor of 100 may be applied to the initial minimal dilution of 50,000 to represent the dilution attained before an effluent may reach the shore. This is actually quite conservative as discharges most of the time will be further offshore and are not continuous. Particles in discharge will sink, and onshore transport, generally dependent on onshore winds, is not constant. The issue is to determine what the least dilution and greatest pollutant level may be at the shoreline, the point of interest for the consumption of raw shellfish. Therefore, the applicable bacteria standard would be the one designed to protect for the consumption of raw shellfish. When the available dilution is considered, the bacteria sampling data from the summers of 2000 and 2001 pass this requirement. The most stringent of Alaska's bacteria standards was not violated near shore by the cruise ships sampled as long as they were moving at 6 knots or more and were more than one nautical mile from shore.

Conclusions

Because Alaska's bacteria standards incorporate the averaging principle they are not about worst case. Instead, these standards are concerned with measurements over time. The 2000 monitoring data demonstrates that exceedences of the most stringent bacteria standard would not result from cruise ships discharging at six knots or more when at least one mile from shore.

As previously noted, water quality standards are based on the monitoring of an indicator pollutant, bacteria. Viruses, protozoa and pathogenic bacteria strains are not measured. Presence of pathogenic microorganisms is dependent on the infection rate in the contributing population and survival of these other microorganisms will be different compared to the indicator bacteria. New analytical techniques for directly detecting the presence of pathogenic microorganisms are being researched. However, nearly 60 years

of experience with setting standards using indicator bacteria has proven to be protective of human health.

As a post script, data from the ships in the 2001 season show that well functioning onboard advanced treatment systems (the Zenon aerated membrane ultra filtration system and the ROCHEM Reverse Osmosis/UV disinfection/activated carbon systems) can attain a mean fecal coliform concentration of 2 FC/100 mL, and a median value of 1 FC/100 ml with a range from 1 to 60 FC/100 mL as determined by the multiple tube fermentation technique. It is obvious that there would be no impact on fecal coliform water quality standards by any of these discharges.

Small cruise vessels do not currently have holding tanks. Consequently, they are continuously discharging, although the rates of discharge may be small. When at anchor, or drifting, or tied up in port, the discharges from small cruise ships will have substantially less mixing and there is an increased potential for exceedences of bacterial standards both near the vessel and nearshore. Small vessel issues will be discussed further in Section IX.

References

Alderisio, L. A., DeLuca, N., "Seasonal Enumeration of Fecal Coliform Bacteria from the Feces of Ring-Billed Gulls (*Larus delawarensis)* and Canada Geese (*Branta canadensis*), Applied and Environmental Microbiology, Vol. 65, No. 12, 1999.

Chamberlin, C. E., Mitchell, R., "A Decay Model for Enteric Bacteria in Natural Waters", Water Pollution Microbiology, John Wiley & Sons, 1993.

Eaton, A. D., Clesceri, L. S., and Greenberg, A.E. Standard Methods for the Examination of Water and Wastewater, APHA, 19th Edition, 1995.

Hurst, C. J., Crawford, R. L., Knudsen, G.R., McInerney, M. J. Stetzenbach, L. D. Manual of Environmental Microbiology, Second Edition, 2002.

Orange County Sanitation District, Annual Report to California Regional Water Quality Control Board and the EPA, 1989.

Parkin, T., "Analysis of Lognormal Data", Selected Topics in Statistics for Research Microbiologists, American Society for Microbiology Workshop, Anaheim, CA. 1990.

Shumway, R. H., Azari, A. S., "Estimating Mean Concentrations When Some Data are Below the Detection Limit", Final Report Contract ARB-A7330045, California Air Resources Board, 1988.

Thomas, H. A. Jr., "Statistical Analysis of Coliform Data", Sewage and Industrial Wastes, Vol. 27, No. 2, 1955.

Section IV

The Impact of Wastewater Nutrients on Alaska Marine Waters

Marlin Atkinson, Michael Stekoll, and Lincoln Loehr

Summary

High nutrient concentrations (nitrogen, phosphorous) in wastewater discharge can, under the right conditions, promote phytoplankton blooms in receiving waters, altering the immediate marine environment. The Science Advisory Panel investigated the possibility that nutrients in cruise ship wastewater discharge could stimulate unwanted events in Alaska marine waters.

The limiting nutrient for phytoplankton growth in Southeast Alaska marine waters is dissolved nitrogen in the form of ammonia (NH_3/NH_4^+), nitrate (NO_3^-), and/or nitrite (NO_2^-). In open waters the total of nitrate plus nitrite (NO_x) is usually much more important than ammonia. But ammonia becomes more important in estuarine situations or near wastewater discharges. Naturally occurring nitrate concentrations in Southeast Alaska waters vary from about 30 micromoles per liter (μM)[29] in the spring to around 1 μM during the late summer and early fall. Levels of nitrite and ammonia are typically much less than nitrate in open waters. The Panel estimates the maximum mean total nitrogen concentration in large cruise ship wastewater discharges to be 5 mM. By applying a minimum mixing factor of 50,000[30] for a moving cruise ship, the wastewater total nitrogen concentrations are one-tenth to one-hundredth of the lowest Alaska marine water background concentration, or about 0.1 μM. This amount of nitrogen can be converted to a very small amount of phytoplankton over the next several days, approximately 0.03 μg chl per liter. This amount of chlorophyll is only a hundredth to a thousandth of the standing phytoplankton. New treatment requirements and regulations for 2003 may further reduce the amount of nutrients discharged in cruise ship wastewaters.

Findings from Cruise Ship Wastewater Sampling and Analysis

Water discharged from cruise ships into the ocean has higher nutrient concentrations than the ocean. The discharge water is composed of different types of wastewater from various locations within the ship and, depending on the ship, includes gray water (i.e. that from showers and sinks, laundry facilities and the galley) as well as treated sewage. The

[29] To convert these molar concentrations to micrograms/liter, multiply by 14, which is the atomic weight of nitrogen. Millimole (mM) is one-thousandth of the molecular weight of nitrogen per liter. Micromole (μM) is one-millionth the molecular weight of nitrogen per liter.

[30] A mixing factor of 50,000 is estimated for a large cruise ship traveling at the minimum allowed speed of 6 knots and discharging wastewater at 200 m^3/hr. This scenario is considered a typical average worst case. (See Section I)

discharge of raw sewage or untreated black water is prohibited in Alaska. The concentrations of total nitrogen and phosphorus (as phosphate) in these different waters have concentrations ranging over several orders of magnitude (Smith, 2000) based on summer 2000 data. Initial sampling of cruise ship wastewater, carried out in summer 2000, revealed this large variability. Sampling in summer 2001 was consistent with 2000 samples (see Section II). The 2000 and 2001 analysis only included inorganic ammonia. The first data analysis and synthesis assumed a fixed relationship between ammonia and total nitrogen, based on a wide survey of the literature on sewage (Smith 2000). The ratio assumed was total nitrogen equals 3.3 times ammonia. Review of sample analysis from 6 ships during the 2002 sampling shows total nitrogen to ammonia ratio varies from 1.2 to 99. The 2002 sampling and analysis requires further review. Thus the following estimates are based on the 2000 and 2001 ammonia data, converted to total nitrogen by the factor 3.3, as discussed above

The statistical means for the total nitrogen content of graywater, which is the significant majority volume of the cruise ship wastewater discharged to the ocean, lies between about 20 to 100 mg/l (1.5 to 5 mM) depending on different sub-sets of the data (Section II). A few samples had high concentrations, resulting in a higher mean. Untreated black water, which is not discharged to the ocean, has means of about 300 to 400 mg/l (20 to 30 mM). At this point in the development of sampling and analysis, each data set is biased by the types of water sampled within the confines of the ship. Better sampling during 2002 and in subsequent years will produce a higher quality data set with lower variability. New regulations for graywater discharge in 2003 and introduction of advanced or enhanced treatment technology throughout the large cruise ship fleet may reduce nutrient concentrations even further. But for the purposes of our evaluation, the Panel conservatively estimates that discharged water can have a total nitrogen concentration up to 5 mM (the upper limit of the mean).

Preliminary data from 2002, in which total nitrogen and phosphorus were directly measured in discharge water, are consistent with the above estimates. Based on 12 samples, the mean total nitrogen was 3.0 mM (5 mM was the maximum mean from 2000 and 2001) and the mean total phosphorus was 0.9 mM.

For a large cruise ship discharging at a rate of 200 cubic meters per hour and traveling at the minimum allowed speed of 6 knots, the mixing will be greater than 50,000 to 1. (See Section I) An initial dilution factor of 50,000 in the near field for a moving ship gives concentrations of (5mM/50,000 =) 0.1 µM total nitrogen.

Background Levels of Nutrients in Alaska Waters

The concentration of nutrients in surface ocean water varies seasonally (Hood & Zimmerman 1986). In winter, the higher-concentration deeper water, rich in nutrients, mixes to the surface giving highest concentration of nitrogen near 40 µM nitrogen (as nitrate and nitrite). As summer progresses, the surface layer is confined to about 20 m depth. Nutrients are consumed by phytoplankton resulting in a peak of primary production during the spring. Nearly all production occurs in these spring-summer

months and corresponds to the amount of nutrients trapped in this surface layer. Additions of nutrients will result in increases in the overall production of plant material, or phytoplankton. This scaling process is well known and Smith (2000) estimates the increase in primary production. The data below describes a typical seasonal cycle in nutrient mixing uptake and plant production in Southeast Alaska (near Juneau and Sitka, with some data from Prince William Sound). As stated above we estimate that the maximum concentrations of nitrates plus nitrites from moving cruise ship discharges after dilution are about 0.1μM. In spring, the concentration of nitrate plus nitrite in surface water starts at 30 μM, nearly 300 times higher than 0.1 μM and decreases toward 1 μM during late summer and early fall (see Figure IV-1), still at least 10 times higher than the diluted discharge. It is evident from these estimates that the discharged water will have little impact on the natural nutrient cycle. Accumulation of nutrients in sediments will also be very small.

Discharge from small passenger ships, which are allowed to discharge moored or at anchor, may have some limited potential to promote phytoplankton blooms in receiving waters. However, small fleet discharges represent only 2.5% of the total cruise ship wastewater discharge into Alaska waters. A small ship will typically discharge 1 m^3/hr whereas a large cruise ship may discharge at 200 m^3/hr. (Section IX) Thus, the nutrient impact of small ships, even during stationary discharge, is likely to be small. However, repeated discharges by small ships into a small embayment may create a significant phytoplankton bloom if water exchange within the bay is minimal. (See Section VII)

Large cruise ships employing advanced treatment technology may be allowed to discharge in port or at anchor provided they meet stringent effluent parameters for fecal coliform, suspended solids, biochemical oxygen demand and pH. It is assumed that advanced technologies well reduce nutrient concentrations in the wastewater discharge. This assumption should be validated through continued sampling and analysis in 2003 and subsequent years.

Summary of nutrients in SE Alaska waters

Stekoll et.al (1992, 1998 & 2001) report nutrient data from relatively protected areas near Juneau and Sitka, with some data from Prince William Sound. There is considerable variability in nutrient concentrations in surface waters (less than 20m). Below 20m the values of nutrients are relatively high throughout the year.

Nutrients in marine waters can be summarized as follows:

Nitrogen: As stated above nitrate (NO_3^-) is usually the dominant form of nitrogen in marine waters. Nitrite (NO_2^-) is usually not very important. Ammonia (NH_3) can be important in contained bays near cities and villages (wastewater discharges) and near stream outfalls during salmon runs. Nitrate varies from 0 to 40 μM over the year. (Figure IV-1) Low values (0 – 3 μM) occur from May to October. Values increase in November and peak in December through February. The peak is due to mixing from storms plus the

lack of on-going photosynthesis in the winter. The cycle is fairly predictable from one year to the next. The values of nitrate do not vary much by depth in the 0-10m zone.

Ammonia (plus ammonium ion, NH_4^+): Values are usually in the 0-4 μM range. In Auke Bay the ammonia values peak in May-June at about 6μM. The source of ammonia is probably bacterial/microbial/zooplankton excretion.

Nitrogen is probably the limiting nutrient in SE Alaska waters, but phosphate may also be limiting at times.

Phosphate: From Figure IV-2 it can be seen that the phosphate levels parallel those for nitrate except that the concentration of phosphate is typically much lower than nitrate. Phosphate peaks at 2-3μM. Phosphate concentrations may stratify with depth. The surface layers lose phosphate earlier than the deeper layers.

Silicate: Silicate is an essential nutrient for diatom organisms in the phytoplankton. Silicate values are from Auke Bay studies only. The silicate concentration rises and falls parallel to the nitrate and phosphate concentrations. Values peak at 60μM around March. Silicate is probably not a limiting nutrient at any time of the year.

Temperature and Salinity: There is a predictable cycle (Figure IV-3) of near surface temperature and salinity in the inside waters. In winter the temperatures are low at 2-4^{o}C. At the same time the salinities are relatively high at 30-34 parts per thousand (ppt). Salinity drops only slightly as temperatures increase through August. Typical temperatures are: April, 7^{o}C, May, 10^{o}C, August, 14^{o}C. Salinities during this time drop to about 29-30 ppt. During August to September there is a rapid salinity drop to less than 28 ppt. The salinity change is due to the volumes of fresh water from rainfall and snowmelt, which is fairly high in Southeast Alaska. As the temperature begins to drop (and rainfall is captured on land as ice and snow) the salinity increases again (see Figure IV-3). February is the time of coldest temperature and highest salinity. August/September has the warmest and least saline water. In estuarine areas, the surface salinity often drops to zero because the water is primarily from surface runoff (rivers, streams, etc.) passing through the estuary. Salinity/temperature stratification (thermoclines and haloclines) occurs in the spring and summer. Mixing occurs in the fall and winter.

Phytoplankton blooms. Figure IV-4 shows blooms of diatoms in April as sunlight becomes more abundant. Secondary blooms may occur in May and June as upwelling events occur, but these are usually smaller and short lived. The spring bloom always goes through a succession of species but this varies from year to year. The zooplankton bloom follows the phytoplankton bloom and lasts well into the summer.

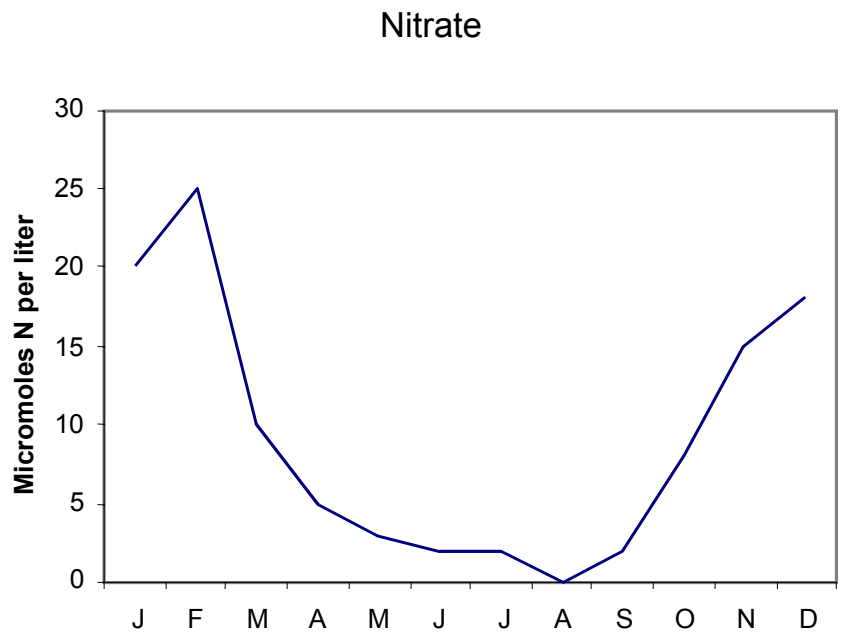


Figure IV-1. Nitrate concentrations in SE Alaska throughout the year (from Stekoll, 2001).

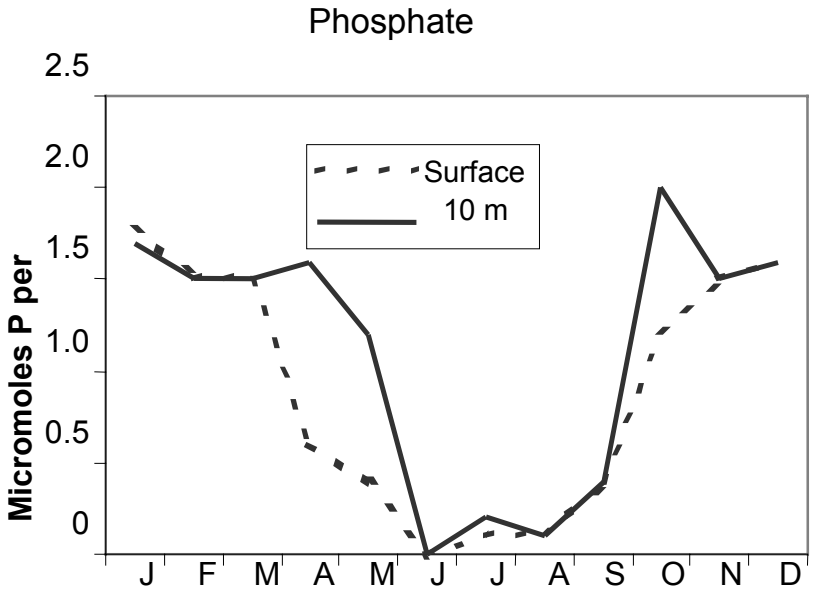


Figure IV-2. Phosphate concentrations in SE Alaska throughout the year (from Stekoll, 2001).

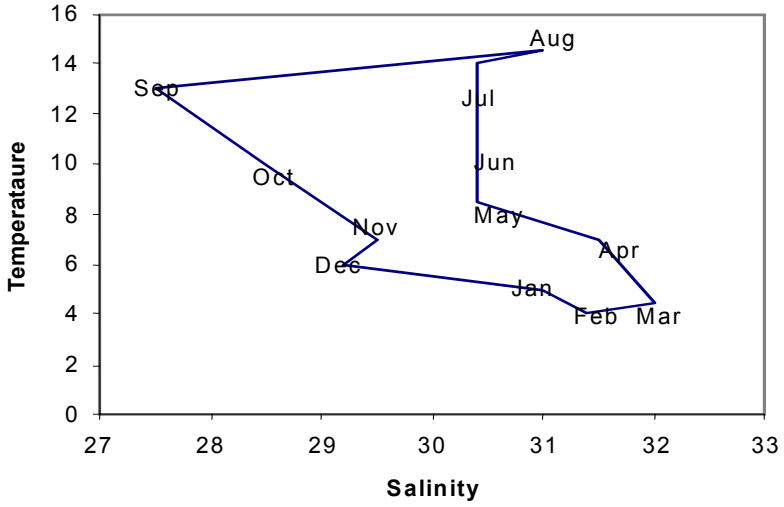


Figure IV-3. Cycle of temperature and salinity in surface waters throughout the year in SE Alaska (from Stekoll, 2001).

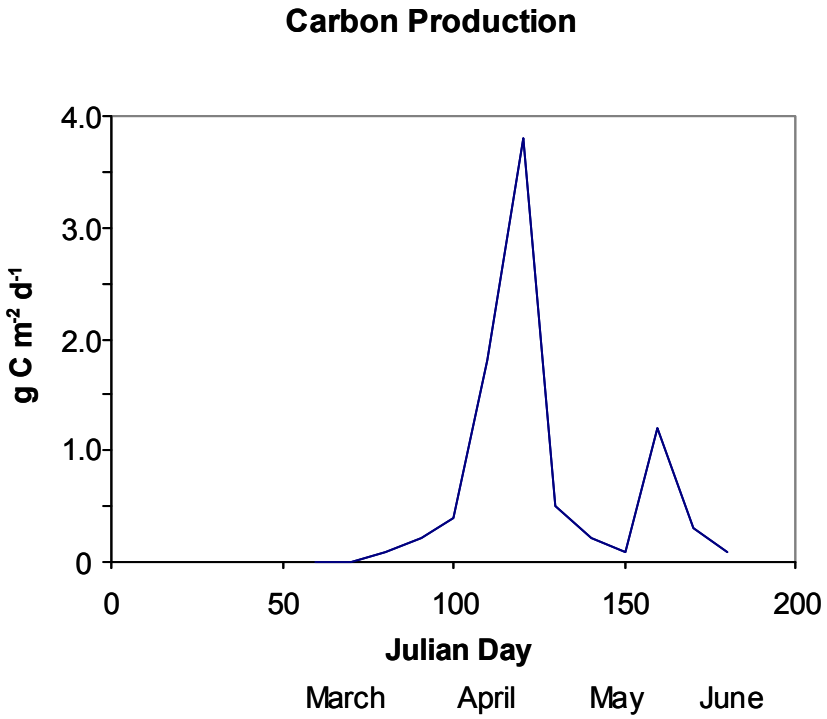


Figure IV-4. Carbon production from phytoplankton photosynthesis in the spring and early summer in Auke Bay, SE Alaska (from Stekoll, 2001).

References:

Hood, D. W. and S. T. Zimmerman (eds). 1986. The Gulf of Alaska. Physical environment and biological resources. NOAA, US Dept of Commerce, Washington D.C.

Smith, S.V. 2000. Discharge of Organic Matter and Nutrients. Cruise Ship Wastewater Discharge into Alaskan Coastal Waters. Alaska SeaLife Center Technical Report 2000-1, p17-29

Stekoll, Michael S. 1998. The seaweed resources of Alaska. In: Critchley & Ohno (eds), Seaweed Resources of the World. Japan International Cooperation Agency, Yokosuka, 258-265.

Stekoll, Michael S. and Page V. Else. 1992. The Feasibility of *Macrocystis* Mariculture in Southeast Alaska. Japan Overseas Fishery Cooperation Foundation, Tokyo. 171 pp.

Stekoll, Michael S. 2001. Unpublished data presented to the Science Advisory Panel, December 2001.

Zieman, D. A. and K. W. Fulton-Bennett (eds). 1990. APPRISE – Interannual variability and fisheries recruitment. The Oceanic Institute. Honolulu, HI.

Section V

Evaluation of the Effect of Cruise Ship Discharges on the Quality of Marine Sediments

Ken Hall, C-J Beegle-Krause, Lincoln Loehr, and Kenwyn George

Summary:

Many contaminants are relatively insoluble in seawater and tend to adsorb to particles in the wastewater effluent and in the receiving environment. These contaminants settle and accumulate in the bed sediments and can often present a chronological record of contamination in an area. Bioturbation (the disruption of sediment by organisms, e.g. by churning or burrowing) can mix sediments and diagenetic (e.g. compaction, dissolution and cementation) processes can redistribute contaminants in the sediment profile.

This paper starts by describing contaminants in sediments in the Strait of Georgia, which are associated with human activity (but not tied directly to cruise ship discharges). Sediment contaminant levels are compared to several sediment guideline values. Next this paper discusses sediment contaminants and associated benthic studies associated with municipal wastewater discharges. Contaminants in cruise ship discharges are evaluated, focussing on metals and total suspended solids effluent data. Estimates of metals in the suspended solids are compared directly to sediment guideline values and some metals are shown to exceed sediment guideline values in the suspended solids. Copper is selected as the contaminant most likely to cause a concern. The suspended solids in cruise ship discharges are widely dispersed and typically settle in deep depositional basins along with natural suspended sediments from other sources, notably major rivers. The incremental increase in copper sediment concentrations resulting from the combined particles from cruise ships with the natural deposition of particles is quantified for several conservative scenarios and compared to sediment guideline values and background sediment copper concentrations. The Panel concludes it is unlikely that there would be environmental impacts of contaminants in sediments that could be associated directly with cruise ships.

Sediment Contaminants in the Strait of Georgia:

The Strait of Georgia is a semi-enclosed basin between Vancouver Island and the mainland of British Columbia that receives discharges from anthropogenic (substances of human origin) sources such as sewage treatment plants, industrial wastes and non-point sources (urban storm water and agricultural runoff). However, since the cruise ships pass through this confined area on their way to Alaska, an evaluation of the contaminants present in the sediments of this area is useful to evaluate potential contaminant contribution from the cruise ships.

MacDonald et al. (1991) determined the trace metals concentrations in sediment cores collected from the Bollenas Basin (>300 m deep) in the Strait of Georgia as well as Jervis Inlet between 1980-1989 (Table V-1). They found surface enrichment of all metals that they attributed to anthropogenic loading. Sediment concentrations of copper, lead, and zinc in the more remote Jervis Inlet were comparable to the deep Bollenas Basin. Zinc in surface sediments exceeded the proposed Canadian interim sediment quality criteria, ISQC (CCME, 2001).[31] Tributyl tin and its degradation products (DBT, MBT) were found in a sediment core from Bollenas Basin (Table V-2). These contaminants were distributed down to 25 cm in the core with the concentrations gradually decreasing with depth (Stewart and Thompson, 1994). Yunker et al. (2000) conducted an extensive survey on the distribution of PAHs (polynuclear aromatic hydrocarbons) in the Fraser River Basin and reported values from the Strait of Georgia (Table V-3). Sediment concentrations of PAHs are considerably lower in the Strait of Georgia than in Vancouver harbour where there is a higher density of ship traffic, discharges from non-point sources (storm water) and combined sewer overflows, which can contain PAHs. Concentrations of PAHs in the Strait exceeded the proposed ISQC for marine sediments. The sediment data do not implicate cruise ship wastewater discharges but do implicate human contributions from a variety of common activities.

Table V-1: Trace Metals in Surface Sediments from the Strait of Georgia, British Columbia[(1)]

TRACE METAL		**SEDIMENT SOURCE**		**SEDIMENT CRITERIA**	
	Bellenas #2	Bellenas #4	Jervis Inlet	ISQC	PEL
Copper	40	44	55	18.7	108
Lead	22	20-24	22	30.2	112
Zinc	120	200	140-160	124	271
Manganese	900	1200	-	-	-

[(1)]MacDonald et al. (1991). All values in mg/kg dry weight. CCME(2001) ISQC = interim sediment quality guidelines (marine sediments) and PEL = probable effects level (marine sediments).

[31] Note that the proposed interim sediment quality criteria are based on threshold effects levels (TELs), which are the lowest of a range of sediment screening levels described by NOAA (1999). Washington State has actually adopted sediment quality standards (Chapter 173-204 WAC) based on apparent effects thresholds (AETs) that are substantially different than TELs. For non-polar organic compounds such as PAHs, Washington's standards are normalized to the organic carbon content of the sediment so the units of concentration may not be directly compared to dry weight-based criteria such as TELs.

Table V-2: Butyltin in Surface Sediments from the Strait of Georgia, B.C.[1]

Organotin Compound	Sediment Concentration (ng/g Sn dry weight)
Tributyltin	2.2
Dibutyltin	1.2
Monobutyltin	0.5

(1) Stewart and Thompson (1994)

Table V-3: Polynuclear Aromatic Hydrocarbons in Sediments [1]

PAH	Strait of Georgia	Vancouver Harbour	ISQC
Naphthalene	35-60	26-290	34.6
Acenaphthylene	7-10	7.2-100	5.87
Acenaphthene	7-13	8-62	6.71
Fluorene	24	22-110	21.2
Phenanthrene	92-100	110-550	86.7
Fluoranthene	120	140-730	113
Dibenz[a,c/a,h] Anthracene	7-10	14-54	6.2
C^1-naphthalenes	54-82	110-220	20.2

(1) Yunker et al. (2000) with values in ng/g dry weight. ISQC = interim sediment quality criteria for marine sediments (CCME, 2001).

Sediment Contaminants from Sewage Treatment Plants:

The Iona Island sewage treatment plant collects municipal wastewaters as well as stormwater runoff from the metropolitan area of Vancouver, B.C. and after primary treatment, discharges the effluent 7.2 km offshore through twin semi-parallel diffusers (500 m long) at a depth of 72-106 m. Extensive investigations have been conducted by the Greater Vancouver Regional District as part of their liquid waste management plan. The environmental impacts of these effluents have been evaluated by monitoring the distribution of sediment contaminants and an assessment of the benthic community structure (EVS Consultants, 2002).

Sediment concentrations of cadmium, silver, chlorobenzenes, total-PCBs, coplanar PCB #77 and several other PCB congeners, nonylphenol and its ethoxylates, and certain sterols showed trends in distribution that are related to the outfall. The trace metals [arsenic (AS), chromium (Cr), copper (Cu), nickel (Ni)], the pesticide aldrin, and the PAHs namely acenaphthene, acenaphthylene, naphthalene, pyrene, and 2-methyl naphthalene all exceeded the proposed ISQC values at one or more stations in a linear transect north and south of the outfall area. More detailed spatial studies on the distribution of silver in the sediments (300-700 ng/g dry weight) have demonstrated that it is a good sedimentary tracer of effluent impacts on sediments (Gordon, 1997). Sediment fecal coliforms as well

as the fecal sterol, coprostanol, also appear to be good tracers for effluent distribution from this point source discharge (Hodgins and Hodgins, 1999; EVS Consultants, 2002)

An analysis of the benthic invertebrate community structure, over a two-year period at 16 stations along the 80 m depth contour through the outfall area, demonstrated a drop in the mean number of taxa near the outfall but no significant reduction in the total biomass of benthic invertebrates. There were higher numbers of polychaetes, but lower numbers of ophiuroids (brittle stars) and crustaceans (amphipods) in the near-field (outfall) area compared to reference stations. Guidelines for lead and some PCBs (polychlorinated biphenyls) were exceeded in some English sole livers and Dungeness crab hepatopancreas but there was no difference between the near-field (outfall) and reference stations. A histopathological tissue examination of these organisms (sole and crabs) revealed no patterns of altered morphology between the two areas. Presently, the overall environmental hazards posed by the sediment contaminants from the Iona Island STP outfall appear to be relatively low. (EVS Consultants, 2002).

Wastewater discharges from the city of Victoria are treated by screening prior to discharge to the Strait of Juan de Fuca through two long outfalls at MacCaulay and Clover Points. This area is mixed and flushed well due to the strong tidal currents. Only two contaminants, namely mercury and 1,4-dichlorophenol, have been found in sediments at levels of concern and associated with one of the two outfalls (Chapman et al. 1996).

Contaminants Discharged from Cruise Ships:

To put the discharges of cruise ships into perspective in terms of sediment contaminant discharges, calculations can be done to determine the level of contaminants that could be associated with the solids discharged from a ship and compared to those levels in the sediment quality criteria. Total suspended solids (TSS) data collected from cruise ships (large and small) during the 2001 season show a large range of TSS concentrations but an overall assessment of these data show that median or geometric mean values of TSS are less than 150 mg/L. 150 mg/L TSS is a conservative value for calculation purposes. This is also the permitted discharge limit set by the State of Alaska so it will represent the maximum TSS values in the future and not the median as more vessels come into compliance. Using trace metals as an example and assuming that 75 % of the measured trace metals are associated with the particulate fraction of the wastewater, one can calculate a possible metal concentration in the solid fraction of the wastewater[32] and compare the calculated concentrations to various sediment quality criteria (Table V-4).

[32] A sample calculation follows: A geometric mean concentration for copper, based on the data for large cruise ships gray water and blackwater from 2001 and for small cruise ships for 2002, is 82.86 µg/L. 75% of that concentration, or 62.145 µg/L, is assumed to be associated with the particulate phase. When 62.145 µg/L is divided by 1000 to convert to mg/L, it equals 0.062145 mg/L. 0.062145 mg/L of copper divided by 150 mg/L of total suspended solids equals 0.0004143 which is 414.3 parts per million or 414.3 mg/kg.

The calculations show that the TSS particles in the effluent exceed various sediment criteria for As, Cu and Zn. However, this comparison is for the solids before discharging. As these solids leave the ship and undergo turbulent mixing from the vessel's passage, the particles are spread over an area comparable to the width of the wake turbulence (e.g. 100 m) very quickly (less than 15 minutes). The smaller particles will take days to settle on the bottom, if they settle at all, and larger particles will sink more quickly. Many particles consist of organic matter and some of those particles will be consumed before they can settle. As these particles move through the water column, they will be further dispersed by tidal currents, eddies and turbulent mixing. The longer the particles are suspended in the water column, the farther from the point of entry they are likely to travel before they can settle on the bottom.

Table V-4: Trace Metals Associated with Solids from Cruise Ships

Trace Metal	Liquid Effluent Concentration (µg/L)	Metal Solids Concentration(mg /kg)	Criteria (mg/kg)		
			ISQC	PEL	AET
As	9.20	46	7.24	41.6	57
Cr	3.42	17.1	52.3	160	260
Cu	82.86	414.3	18.7	108	390
Pb	2.96	14.8	30.2	112	450
Zn	130.66	653.3	124	271	410

1. Metal effluent concentrations represent a geometric mean from three data sets, namely large cruise ships gray water (2001), large cruise ships black water (2001) and small cruise ships (2002).
2. Concentration in solids are based on a value of 150 mg/L TSS and assuming that 75% of the total metal is associated with the particulate phase in the wastewater.
3. CCME (2001) interim sediment quality criteria (ISQC) and probable effects level (PEL) for marine sediments.
4. WAC 173-204-320. Washington State sediment quality standards based on apparent effects threshold (AET).

In addition to dispersion in the ship's wake, sediment transport from high sediment sources such as large rivers, e.g. Fraser, Skeena, Stikine, as well as high sediment loads from melting glaciers, e.g. Taku, will effectively combine with the particle associated contaminants from cruise ship discharges and reduce their concentration in the bottom sediments. Table V-5 presents examples of natural deposition rates in deep waters in SE Alaska measured by several means and reported by Rescan Consultants (2000). Comparisons with Puget Sound and Southern California are also provided.

For these reasons, it is very unlikely that there would be any environmental impacts of contaminants in sediments that could be associated directly to the cruise ships.

Table V-5: Natural Deposition Rates

Sedimentation rate	Depth	Location	Method	Reference
13.3 g/day/m^2	153 m	Lynn Canal	Sediment trap	Rescan Consultants (2000)
13.9 g/day/m^2	225 m	Lynn Canal	Sediment trap	Rescan Consultants (2000)
38.8 g/day/m^2	291 m	Lynn Canal	Sediment trap	Rescan Consultants (2000)
38.6 g/day/m^2	291 m	Lynn Canal	Sediment trap	Rescan Consultants (2000)
1.88 g/day/m^2	60 m	Lynn Canal	Sediment trap	Rescan Consultants (1990)
17.0 g/day/m^2	290 m	Lynn Canal	Sediment trap	Rescan Consultants (1990)
34 g/day/m^2	-	Stephen's Passage	-	CH2MHILL (1996) Reported by Rescan Consultants (2000)
41 g/day/m^2	-	Taku Inlet	-	CH2MHILL (1996) Reported by Rescan Consultants (2000)
5.3 g/day/m^2	-	Lynn Canal	Core Pb-210	Rescan Consultants (2000)
8.2 g/day/m^2	150 m+	Puget Sound	Core Pb-210	Crecelius (pers com 2002)
32.9 g/day/m^2	150 m+	Puget Sound	Core Pb-210	Crecelius (pers com 2002)
0.3 g/day/m^2	60 m+	So. California	Estimate	Emery (1960)

Development of a Deposition Model

The panel has developed a scenario to evaluate the potential for copper to enter the sediments in SE Alaska from cruise ship wastewater discharges. This scenario shows how one could evaluate other potential sediment contaminants from cruise ship wastewater discharges. The panel selected copper as the contaminant with the most potential to be a problem based on the wastewater priority pollutant data from cruise ships obtained in 2001 and 2002. The analysis requires several assumptions:

- Taking a realistic range of copper in effluents.
- Assuming that a percentage of that copper binds to suspended solids in the effluent.
- Assuming a mass of copper delivered by a reasonable number of cruise ships to an area over a year.
- Assuming an area over which the copper may settle, calculating a rate in milligrams per year per square meter.
- Comparing that to a reasonably conservative estimate of the rate of natural sedimentation.

This process leads to an estimate of copper concentration above the background that could result in the sediments, and would also represent a steady state condition, not an additive condition. The concentrations so determined could be compared to various sediment quality values that have been derived. The detailed methodology and calculations follow:

1. A large cruise ship discharges a graywater/treated blackwater mix at 200 m^3/hr at a minimum speed of 6 knots (about 11,000 m/hr) at least one nautical mile (about 1850 m) from the nearest shore. So in one hour, the ship travels 11,000 m.

2. An average suspended solid concentration in the wastewater effluent is 150 mg/l. (Note, as cruise ships come into compliance with the treatment standards required by Alaska, the average suspended solids will decrease.)

3. 75% of the measured constituents of concern (e.g. trace metals) are bound to the suspended solids.

4. Using copper as an example, from Table V-4, the geometric mean of the concentration in the effluent is 82.9 ug/l.

5. The amount of copper discharged in one hour along 11,000 meters of ship trackline would be:

   $$(83 \text{ ug/l Cu})(0.75)(10^{-3} \text{ mg/ug})(200 \text{ m}^3)(1000 \text{ l/m}^3) = 12{,}450 \text{ mg Cu}$$

6. The amount of copper discharged per meter that the ship travels is given by:

   12,450 mg Cu / (11,000 m ship track) = 1.13 mg Cu/m shiptrack

   However cruise ships often travel faster than 6 knots and/or may discharge at a lower rate than 200 m^3/hr.

7. Three vessels travel exactly the same trackline each day during the cruise ship season (about 150 days). For this calculation we are assuming that accuracy in following another ship's track is with 100 m, a very unlikely event.

8. The amount of copper discharged per meter from three ships over a cruise season of 150 days is:

   (1.13 mg Cu/m ship-track)(3 ships/day)(150 days) = 509 mg Cu/m ship-track/year

   The assumption of three ships a day for 150 days is a greater release rate than actually occurs for most Southeast Alaska waters, but might be a feasible release rate for some limited areas

9. Consider three options. The first option is that this copper is rapidly mixed in the water out to a width of 100 m perpendicular to the track, but then does not spread any further and eventually settles to the bottom along a 100 m swath. The second option is that the copper is deposited in a 100 m swath, but the ship tracks are not exactly the same. The third option is that the copper binds to very small particles that will be

spread over a much wider area and in the case of a channel area 2 nautical miles wide, would settle along a 3,500 m swath. The amount of copper added to each square meter of sediment surface per year under these assumptions is:

option 1: (509 mg Cu/year/m)/(100 m) = 5.1 mg Cu/year/m^2
option 2: (509 mg Cu/year/m)/(300 m) = 1.70 mg Cu/year/ m^2
option 3: (509 mg Cu/year/m)/(3,500 m) = 0.15 mg Cu/year/m^2

Notice that if the ship tracks differ by 100 m (i.e. a 300 m wide swath results from the 3 ships), the amount of copper/m^2 added to the sediments drops by a factor of 3 (from option 1 to option 2). Then notice that letting the copper drift a mile to either side of the main ship track decreases the copper/m^2 added to the sediments by more than a factor of 10 (from option 2 to option 3).

In truth, the fine suspended solids discharged from the ship will fall slowly to the bottom while mixing with eddies, and washing back and forth with the tides. This slow rain of particles will spread away from the discharge point in all directions. Individual particles could fall near the ship track, miles away from the ship track or not sink at all. The Panel believes that all the above estimates of added copper/m^2 are overestimates by factors of 10.

10. To the above numbers we now factor in the rate of natural sedimentation. Suspended sediment trap studies and analysis of sedimentation rates from cores in Southeast Alaska have identified sedimentation rates varying from 1.88 gm/day/m^2 to 41 gm/day/m^2. Sedimentation rates are greatest for deeper waters. Even in Puget Sound, Washington, sedimentation rates below 150 meters vary from 8 to 33 g/day/m^2. The available data suggest that a natural sedimentation rate of 5 g/day/m^2 would serve as a conservative low estimate for this analysis. Using the low rate of sedimentation of 5 g/day/m^2 we can determine a conservative yearly rate of sedimentation as:

    (5 g/day/m^2)(365 day/year) = 1825 g/year/m^2

    Note that in deeper areas (where more sediments collect) individual particles will take longer to sink to the bottom, and thus may be carried farther away. Also, in shallower open areas (where fewer sediments collect) such as sills where the particles have a shorter travel to the bottom, the currents are likely to be stronger, again allowing the particles to travel farther before coming to rest on the bottom. This is why the panel believes that the following estimates in step 11 of the increases in copper concentration in bottom sediments attributable to cruise ship discharges are very high compared to what happens in nature.

11. To determine the additional copper contributed to the sediments from cruise ship discharges under the different options from step 9, the rate of copper addition computed in step 9 must be divided by the rate of natural sediment addition shown in step 10:

    option 1: (5.1 mg Cu/year/C)/(1825 g/year/m^2)(1000 mg/gm) = 2.8 ppm
    option 2: (1.7 mg Cu/year/m^2)/(1825 g/year/m^2)(1000 mg/gm) = 0.9 ppm

option 3: (0.15 mg Cu/year/m^2)/(1825 g/year/m^2)(1000 mg/gm) = 0.08 ppm

12. The option 1, 2 and 3 values of 2.8, 0.9 and 0.08 ppm may be compared to any identified sediment reference values. Note that there are many sediment reference values available, but exceeding one does not necessarily mean there is harm. Reference values are commonly used to determine whether any additional assessment, typically by bioassays or by benthic population studies, is necessary. NOAA has developed Screening Quick Reference Tables (SQRTs) and identifies a range of marine sediment values for copper. These are:

    18.7 mg/kg = Threshold Effects Level (TEL)
    34 mg/kg = Effects Range-Low (ERL)
    108.2 mg/kg = Probable Effects Level (PEL)
    270 mg/kg = Effects Range Median (ERM)
    390 mg/kg = Apparent Effects Threshold (AET)

    Canada uses the 18.7 mg/kg level as a proposed interim sediment quality guideline for copper. Washington has adopted 390 mg/kg as a sediment quality standard for copper.

13. The computed increases in copper concentrations in the above options are substantially lower than any of the reference values in step 12. The computed increases in copper in option 1 are small and in options 2 and 3 are trivial.

14. The theoretical increases from the above conservative analyses may also be evaluated in the context of the natural background levels of copper in marine sediments in SE Alaska which are typically in the 30 to 40+ ppm range. (Rescan Consultants, 2000). The naturally occurring copper sediment concentrations actually exceed some of the threshold values that are sometimes used as references for comparison.

Conclusions:

For reasons described in the above steps, the above analysis is a conservative one in all three cases. The analysis shows that copper in cruise ship discharges is not expected to produce problems in marine sediments. Copper was selected for this example because the Panel believed it had the greatest potential to present an environmental problem among the pollutants present. The same type of analysis for other constituents would most likely produce similar demonstrations of non-problems. This is actually an expected result since areas of sediment contamination in the United States and Canada are usually related to industrialized waterways or areas with historic inputs from stationary, continuous point source discharges, discharges of storm water or combined sewer overflows. The characteristic of such discharges is that they have much less dilution than do large cruise ships.

References:

CCME. 2001. Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment, Ottawa, Ontario.

Chapman, P.M., M.D. Paine, A.D. Arthur, and L.A. Taylor. 1996. The Triad Study of Sediment Quality Associated with a Major Relatively Untreated Marine Sewage Discharge. Mar. Poll. Bull. 32: 47-64.

Emery, K.O. 1960. The Sea off Southern California: A Modern Habitat of Petroleum. John Wiley and Sons, Inc. 366 pp.

EVS Consultants. 2002. Iona Deep-Sea Outfall 2001 Environmental Monitoring Program. Greater Vancouver Regional District, Burnaby, B.C.

Gordon, K. 1997. Sedimentary Tracers in Sewage Inputs to the Southern Strait of Georgia. MSc Thesis, Dept. of Earth and Ocean Sciences, The University of British Columbia, Vancouver, B.C.

Hendricks, T. 1982. An advanced sediment quality model. 247-257 In Willard Bascom, ed., Coastal Water Research Project Bieenial report for the Years 1981-1982. Southern Calidfornia Coastal Water Research Project, Long Beach, CA

Hendricks, T. 1984. Predicting sediment qiuality around outfalls. 127-140 In Willard Bascom, ed., Coastal Water Research Project Bieenial report for the Years 1981-1982. Southern Calidfornia Coastal Water Research Project, Long Beach, CA

Hodgins, D.O. and S.L.M. Hodgins. 1999. Iona Deep Sea Outfall 1999 Environmental Monitoring Program: Effluent Dispersion and Solids Deposition Modelling Study. Greater Vancouver Regional District, Burnaby, B.C.

MacDonald, R.W. et al. 1991. Accumulation of Heavy Metals (Pb, Zn, Cu, Cd), carbon and nitrogen in sediments from Strait of Georgia, B.C. Canada. Mar. Chem. 34: 109-135.

NOAA. 1999. Screening Quick Reference Tables. http://response.restoration.noaa.gov/cpr/sediment/squirt/squirt.pdf

Rescan Environmental Services Ltd., April 1990, Kensington Gold Project Alaska, Environmental Baseline and Technical Background Information, Lynn Canal Oceanographic Data report

Rescan Environmental Services Ltd., 1996, Kensington Gold Project Alaska, Environmental Baseline and Technical Background Information, Lynn Canal Oceanographic Data report

Rescan Consultants, Inc., April 2000 Project 554-5, Kensington Project Data Report Sedimentation Rates

Stewart, C. and J.A.J. Thompson. 1994. Extensive Butyltin Contamination in Southwestern Coastal British Columbia. Mar. Poll. Bull. 28: 601-606.

Yunker, M.B. et al. 2000. Assessment of Natural and Anthropogenic Hydrocarbon Inputs Using PAHs as Tracers. The Fraser River Basin and Strait of Georgia. 1987-1997. Fraser River Action Plan, Dept. of Environment, Vancouver, Vancouver, B.C.

Section VI

The Surface Water Microlayer of the Marine Environment and Potential Impacts of Wastewater Discharges from Cruise Ships

Ken Hall and Alan Mearns

Summary

The surface water microlayer or sea surface film is a complex air-seawater interface 200-300 μm thick containing organic and inorganic material and concentrations of life-forms, often at levels significantly elevated from that of the waters beneath the film. The higher levels of particulates and natural compounds in the sea surface microlayer can sequester or absorb trace metals and organic contaminants. The microlayer is also a stressed environment, effected by wind/wave action and ultraviolet energy absorption. The passage of a vessel's propellers and hull is disruptive to the microlayer and probably causes some unknown quantity of plankton and fish larval mortality.

The Science Advisory Panel investigated the possibility that contaminants from large cruise ship wastewater discharge might adversely impact life-form activity. The Panel concluded that the high dilution of wastewater caused by a large moving cruise ship would prevent significant accumulation of contaminants in the microlayer, even after accounting for the sequestering or enrichment properties of the microlayer. This conclusion is further bolstered by the Whole Effluent Toxicity tests conducted in July 2002 (Appendix 8). Small cruise ships that discharge small amounts of wastewater while anchored or stationary in fjords and embayments may have some limited potential for adverse impact to the fresh water layers found in fjords and embayments.

Introduction:

This review will provide:

- A description of the surface layers of the marine environment
- A characterization of the chemical and biological properties of this zone
- The distribution and toxicity of contaminants in the surface microlayer
- The impact of disturbance or stress on the surface microlayer, particularly with regard to vessel movement.
- The impacts of wastewater discharges from cruise ships on this microlayer.

A Physical Description of the Sea Surface Microlayer

A physical description of the air-seawater interface is presented as a four-layer system with a thin air film in contact with a thin water film. These interface films have properties that are

significantly different than the bulk mixed air and water layers on both sides of this film boundary. A concentration gradient of atmospheric gases occurs in the water film since there is transfer across this boundary.

The air-water interface is a stressed environment, which is subject to dynamic non-equilibrium processes such as wind stress, water evaporation, solar energy flux and atmospheric inputs (Williams et al, 1986). In spite of the complexity of this interface environment, it provides an important aquatic habitat for many aquatic organisms. The specialized organisms that have adapted to this interface habitat are collectively called 'pleuston' while the microscopic component of the pleuston is called the 'neuston' (Wetzel 2001). The development of these aquatic surface oriented communities is most extensive in sheltered, quiescent environments. However, they are still considered to be important in the marine environment (Zaitsev, 1970 ; Wanderschneider, 1979).

A chemical/biological description of this surface microlayer, often called the sea surface film, has been presented as a surface layer of lipids, proteins, polysaccharides and humic substances in the order of 0.1 μm followed by a bacterioneuston layer up to 1.0 μm in thickness (Maki, 1993). Other organisms use the surface tension of this microlayer during different stages of development (e.g. egg adhesion, larval attachment). In reality, when studies are conducted on the surface microlayer, the surface 200-300 μm layer is sampled by various collection techniques and compared to the bulk water underneath (0.1 to 1.0 m).

The Chemical and Biological Properties of the Sea Surface Microlayer

Several studies have been conducted to investigate the chemical and biological properties of the surface microlayer and compare it to the bulk water. In studies off California, Williams et al. (1986) studied the surface film (200-300 μm) and compared it to the bulk water at 10 cm in both the coastal and open ocean environments. They found enrichment factors (film concentration/10 cm conc.) for nutrients, plankton indicators (chlorophyll *a*, ATP) and organic carbon (Table VI-1). There was more protein relative to carbohydrate in the surface film compared to the deeper water. However, the correlations between the various chemical and biological measurements could not be adequately explained, reflecting the complexity of processes that form and maintain surface films.

In similar studies conducted in the Mediterranean Sea off of Marseilles, France, De Souza Lima and Chretiennot-Dinet (1984), found higher levels of particulate organic carbon and nitrogen, carbohydrate, chlorophyll *a*, and ATP in the surface compared to the underlying water at 0.5 m (Table VI- 2). However, primary carbon fixation, attributed to mainly dinoflagellates and diatoms, was slightly lower giving a lower production/chlorophyll *a* ratio and indicating photoinhibition or possible contaminant inhibition in this surface microlayer (Table VI- 2). There is usually inhibition of aquatic photosynthesis in surface waters due to photooxidative destruction of enzymes as well as the inactivation of photosystem II by the UV radiation (Wetzel 2001).

Table VI- 1: Chemical and Biological Characteristics of the Sea Surface Microlayer off California

Station	Sample	Nitrate	Phosphate	Chlor *a*	ATP	DOC	POC
Open Ocean	ssf	0.31	0.21	0.13	0.19	176	30
	10 cm	0.27	0.26	0.08	0.05	83	5.5
Coastal 1	ssf	0.04	0.12	0.79	0.50	134	42
	10 cm	0.05	0.10	1.2	0.44	102	30
Coastal 2	ssf	0.03	0.12	0.75	0.26	126	39
	10 cm	0.02	0.11	0.55	0.28	105	25

Nitrate, phosphate, dissolved organic carbon (DOC) and POC is particulate organic carbon (POC) in µmoles/L, Chlorophyll and ATP in µg/L ssf = sea surface film. Adapted from Williams et al. (1986).

Table VI- 2: Chemical and Biological Characteristics of the Surface Microlayer in the Mediterranean Sea

Characteristic	Surface Microlayer	Underlying Water (at 0.5 m)
POC (mg/L)	3.25	0.48
PON (mg/L)`	0.39	0.06
C/N ratio	10.4	7.9
Chlorophyll *a* (ug/L)	1.53	0.74
ATP (ug/L)	0.98	0.39
^{14}C fixation (ugC/L/h)	5.03	5.35
Prod./Chl *a*	3.5	7.6

Adapted from De Souza Lima and Chretiennot-Dinet (1984)

Studies by Albright and colleagues (Albright, 1980; Bell and Albright, 1982; and Dietz et al., 1976) in the Strait of Georgia, which is highly influenced by the freshwater runoff and high turbidity of the Fraser River, generally found lower autotrophic and heterotrophic activities in the 70-80 µm neuston layer than in the plankton in the bulk water. They concluded that the neustonic microorganisms were not as metabolically active as their planktonic counterparts and were probably under greater stress in this near-surface microlayer.

Therefore there appears to be considerable variability in the microorganism numbers and their activity in the surface microlayer of the marine environment.

Contaminants and Toxicity in the Sea Surface Microlayer

With the higher levels of particulates and natural compounds (carbohydrates, proteins and lipids) in the sea surface microlayer, it is obvious that this interface should provide a favorable environment for contaminants to accumulate since they can adsorb to particulate surfaces or co-solublize or sequester with some of the natural compounds that accumulate at this interface. The literature on trace metals and organic contaminants that accumulate at this interface has been presented by Maki (1993) and is summarized for the marine environment in Table VI- 3.

Table VI- 3: Contaminants in Surface Film Samples from Marine Waters

CONTAMINANTS	SAMPLER	REFERENCE
TRACE METALS		
Cu, Fe, Ni, Pb	Plastic screen	Duce et al. (1972)
Al, Cu, Fe, Mn, Ni, Pb, V	Plastic screen	Piotrowicz et al. (1972)
Cd, Cu, Fe, Mn, Ni, Pb, Zn	Nylon screen	Hunter (1980)
Cd, Cu, Fe, Pb, Zn	Glass plate	Hardy et al. (1985)
Ag, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn	Teflon drum	Cross et al. (1987)
Ag, Cd, Cu, Pb, Zn	Glass plate & Teflon drum	Hardy et al. (1987a)
ORGANIC COMPOUNDS		
DDT, DDE, Dieldrin, Aldrin	Bottle	Seba and Corcoran (1969)
HC, PCBs	Metal screen	Duce et al. (1972)
PCBs, DDT	Metal screen	Bidle & Olney (1974)
HC	Metal screen	Wade and Quinn (1975)
Normal Alkanes	Metal screen	Marty and Saliot (1976)
Normal Alkanes	Metal screen	Hardy et al. (1977)
HC, PAHs	Metal screen	Boehm (1980)
PCBs, DDT, DDD, DDE, PAHs	Teflon drum	Cross et al. (1987)
HC, PAHs, Pesticides, PCBs	Glass plate & Teflon drum	Hardy et al. (1987a)
Alkanes, PAHs	Teflon drum	Hardy et al. (1990)

HC=hydrcarbons, PCBs=polychlorinated biphenyls, PAHs=polycyclic aromatic hydrcarbons.
Adapted from Maki (1993)

As examples, a few studies are presented in more detail below.

In Narragansett Bay, Rhode Island, Duce et al. (1972) found that the concentrations of lead, iron, nickel, copper, fatty acids, hydrocarbons and polychlorinated biphenyls (PCBs) were enriched 1.5 to 10 times in the top 100-150 μm surface microlayer relative to the bulk water at 20 cm below the surface (Table VI- 4). Hardy et al. (1987a) found a variety of contaminants associated with the microlayer in Puget Sound, Washington (Table VI- 5). There was considerable variation in the microlayer contaminants from different areas (Table VI- 6) which probably reflects the proximity to the contaminant sources, namely atmospheric input from fossil fuel combustion products, uncombusted petroleum in surface runoff, and domestic wastewater discharges.

Table VI- 4: Enrichment of Trace Metals and Organic Compounds in the Surface Layer of Narragansett Bay RI

	CONCENTRATION (UG/L)		
SUBSTANCE	**Surface 100-150μm**	**Subsurface 20 cm**	**ENRICHMENT FACTOR**
Fatty acids	94	62	1.5
Hydrocarbons	8.5	5.9	1.4
PCBs	0.45	<0.05	>9
Lead	1.5	0.28	5.4
Copper	1.3	0.26	6
Nickel	13	2.1	6.2
Iron	35	8.2	4.3

Adapted from Duce et al. (1972)

Table VI- 5: Contaminants in the Sea Surface Film in Puget Sound, WA

COMPOUND	**MEAN CONC.**	**MAX. CONC.**	**CONC. UNITS**
Aromatic Hydrocarbons	132	8030	μg/L
Saturated Hydrocarbons		2057	μg/L
Pesticides	0.46	43.8	ng/L
PCBs	631	3890	ng/L
Total Metals (Ag,Cd,Cu, Pb,Zn)	626	4750	μg/L

Adapted from Hardy (1987a)

Table VI- 6: Spatial Variation in Contaminants in the Sea Surface Film in Puget Sound WA

CONTAMINANT GROUP	CONCENTRATION	SITE
Total Metals	1.4 mg/L	Elliott Bay
	0.05 mg/L	Sequim Bay
Polycyclic Aromatic HCs	650 µg /L	Port Angeles Harbour
	10 µg /L	Central Sound & Sequim Bay

Adapted from Hardy (1987a)

In laboratory toxicity tests, Hardy et al. (1987b) found that compared to reference sites, the surface microlayer from urban bay sites in Puget Sound generally resulted in more chromosomal aberrations in developing sole larvae, reduced hatching success of sole larvae, and reduced growth of trout cell cultures. *In situ* hatching success of sole eggs was reduced by half or more in urban bays compared to reference sites. The Puget Sound studies are supported by other research in California (Cross et al. 1987) where larval mortality and chromosomal aberrations were greater in kelp bass in shallow harbor areas compared to deep offshore stations (Table VI- 7). The toxicity correlated well with the contaminant levels (total metals and PAH's) in the surface layer collected by teflon and ceramic drums.

Table VI- 7: Contaminants and Toxicity of the Sea Surface Microlayer Near Los Angeles California

Station	Water Depth (m)	Larval Mort (%)	Chrom Aberr (%)	Total Metals (µg/L)	Total PAHs (ng/L)
15 km offshore	500	4	11	18	35
8 km offshore	60	5	10	75	40
3 km offshore	58	32	29	302	591
Harbor	8	32	23	1173	2654
Harbor	9	32	33	4528	55775
Harbor	9	58	52	12168	38532

Adapted from Cross et al. (1987)

Given that contaminants do affect the microlayer, the question remains whether cruise ship wastewater discharges elevate the microlayer concentrations of contaminants.

Microlayer Disruption, Formation and Biological Activity:

Some information exists on the rate of reformation of the surface layer after disruption. Studies on the physical properties of the organic surface films found they reformed rapidly after disruption (Williams et al., 1980; Dragcevic and Pravdic 1981). Williams et al. (1980) reported that films formed rapidly in eutrophic coastal waters and more slowly in the oligotrophic open-ocean waters. The new films that formed were nearly identical (chemically and biologically) to the previous ones. In other studies, De Souza Lima and Chretiennot-Dinet (1984) found that during calm conditions there was considerable buildup of particulate organic carbon, ATP and chlorophyll *a* at the surface compared to choppy water conditions (Table VI- 8). They also observed that under calm conditions when a visual slick built up on the sea surface that the surface microlayer showed much higher heterotrophic activity estimated by the uptake of radiolabelled glucose (Table VI- 9). Thus protected areas along the coast would be expected to have more calm periods when surface slicks could develop that could enhance the buildup of natural compounds in the surface film and potentially stimulate autotrophic and heterotrophic processes. However, the accumulation of contaminants from anthropogenic sources in coastal areas could have some negative affects on these natural processes.

Table VI- 8: The Effect of Sea State on Biological Characteristics of the Sea Surface Film

PARAMETER	DEPTH	CALM	CHOPPY
POC (mg/L)	ssf	4.62	1.89
	0.5 m	0.56	0.41
Chlorophyll *a* (ug/L)	ssf	2.59	0.47
	0.5 m	0.97	0.50
ATP (ug/L)	ssf	1.54	0.52
	0.5 m	0.43	0.35
Prod./Chl.*a*	ssf	2.61	4.48
	0.5 m	6.06	9.22

Adapted from De Souza Lima and Chretiennot-Dinet (1984). ssf = sea surface film

Table VI- 9: Microbial Activity During Slick Buildup Under Calm Conditions

HETEROTROPHIC VARIABLE	SLICK PRESENT		NO SLICK	
	ssf	0.5m	ssf	0.5m
Vmax (ugC/L/h)	972	26	11	21
Kt + Sn (ug/L)	110	7	0.97	0.98
Tt (h)	114	92	87	47

Adapted from De Souza Lima and Chretiennot-Dinet (1984). ssf=sea surface film.

Vm= max. uptake rate of radiolabeled glucose, Kt= transport constant, Sn= natural glucose conc. Kt+Sn gets higher values for more nutrient rich or eutrophic systems. Tt = time required to turnover the glucose.

Shear caused by ship propellers and hull passage has been found to be disruptive to organisms in the water column. The upper range of shear stress from propellers and tow configurations of barge towboats in the upper Mississippi River was estimated to be about 6300 dynes/cm^2 (Killgore et al., 2001). In ship tank experiments, Killgore et al (2001) found that mortality of early life stages of several freshwater fish was linearly related to shear stresses in the range of 634 to 4743 dynes/cm^2. Morgan et al (1976) found that the amount of shear required to kill fish eggs and larvae increases with shear force and time of exposure. Mean LC_{50} (exposures required to kill 50% of the eggs or larvae) ranged from 125 dyne/cm^2 at 4 minutes exposure of white perch larvae to 542 dynes/cm^2 at 1-minute exposure for striped bass eggs. High turbulence (6370 dynes/cm^2; one event per hour) resulted in 87% mortality to paddlefish larvae; those exposed to low turbulence (1838 dynes/cm2) suffered only 3% mortality (Killgore et al., 1987). Holland (1986) found that the mean catch of ichthyoplankton was reduced in both surface and bottom waters for 90 minutes following the passage of loaded barge trains (moving up-river); however, there was no consistent effect on catches of age-0 and small adult fishes; damage was primarily to fish eggs.

In the open sea, the scale of mortality of plankton, fish eggs, and fish larvae caused by vessel passage is likely to be of very small scale relative to the amount of surface area and volume available. It may also be of small scale in the Inside Passages of Alaska. We do not yet have information on propeller or hull shears caused by large or small passenger vessels, but can guess that they may be in the same range as tow boats and, thus, may cause injury to fish eggs and larvae when they are present. The Panel notes that the physical disruption or injury to organisms in the microlayer by vessels is not under evaluation. However, describing this dynamic allows the discharge of wastewater to be placed in context. In other words, the movement of vessels and other dynamics are likely to be as disruptive, if not more so, than wastewater discharge.

Ultraviolet Energy Absorption and Effects on the Sea Surface Environment

The depletion of stratospheric ozone and the subsequent enhanced ultra violet energy (280-400 nm), especially the more energetic UV-B (280-320 nm) could affect the chemical and biological processes in surface waters. These effects must be considered in the context of other anthropogenic impacts such as discharges from ships.

The high energy of the shorter UV wavelengths can induce the formation of highly reactive, transient chemical species such as hydroxyl radicals as well as relatively stable hydrogen peroxide (H_2O_2), nitric oxide (NO), and carbon dioxide (CO_2) (Mora et al. 2000). The net effects of many of these reactive chemical species from these photochemical reactions are the oxidation of dissolved organic matter, cleavage of humic substances, photoreduction of trace metals, release of complexed/bound species such as phosphate, and the production of relatively stable compounds like organic acids and carbonyl compounds (Mora and Vernet, 2000; Zhou and

Mopper, 1997). These processes can also enhance the geochemical cycling of carbon, nitrogen and sulfur compounds in the marine environment as well as accelerate the degradation of persistant contaminants such as petroleum hydrocarbons and pesticides. The photooxidation of some environmental contaminants can form other compounds, which are more toxic than the parent compound to aquatic organisms (Larson and Berenbaum, 1988).

The photochemical degradation of dissolved organic matter can make compounds more available for bacterial growth especially in coastal areas with higher levels of dissolved organic matter and humic-like substances from land runoff (Kieber et al. 1989). Also, micronutrients such as iron and phosphorus can be released from high molecular weight organic matter and made more available to organisms. The DNA, RNA, and aromatic amino acids of proteins in aquatic organisms have high absorbance coefficients for UV radiation, which can have destructive effects on cellular components. The ultraviolet radiation at the sea surface can decrease algal primary production with the UV-B inhibiting surface photosynthetic carbon incorporation by 25 to 50% (Vernet, 2000). The damage to zooplankton and fish is highly variable, but studies indicate that it can depress the immune system and increase the vulnerability to pathogens. However, many organisms also have biochemical mechanisms to repair cellular damage caused by UV radiation (Zagarese and Williamson, 2000).

Cruise Ship Wastewater Discharges and their Mixing, Dilution, and Impacts on the Sea Surface Microlayer:

The Panel has reviewed nearly 3 seasons of laboratory analysis in an effort to characterize the quality and volumes of gray and black water discharges from the large cruise ships that travel along the coast. These data indicate that there is high variability in the quality of these effluents (Section II). Also, the quality of these discharges continues to improve as the cruise ship industry proceeds to install more advanced treatment systems to comply with the 2001 Alaskan legislation.

The potential impacts of the wastewater discharges will depend on their dilution into the bulk water over their transportation route. This dilution will be a function of the volume of discharge, the discharge rate, hull design of the vessel, propeller design, speed of the vessel during discharge, as well as currents and wind velocity. Recent dilution, dispersion studies using dye discharged into the wastewater of four cruise ships traveling between 9 and 17 knots demonstrated a dilution value between 200,000:1 and 640,000:1 (EPA, 2002). Assuming a slower speed of 6 knots, cruise ship dynamics would still provide a dilution of 50,000:1 or greater. (See Section I).

At these dilution levels, the only contaminant likely to be measured above ambient levels in the seawater would be fecal coliforms. These indicator microorganisms have been measured at several million/100 ml in both gray and black water discharges from cruise ships. However, evidence indicates that there is the potential to concentrate some contaminants 50 to 100 times the ambient level in the sea surface microlayer (Table VI- 5). It appears that these higher

concentration levels in the surface microlayer would overcome the high degree of dilution occurring with the wastewater discharges from the moving cruise ships. Thus, contaminant levels should remain significantly below acceptable water quality criteria even in this surface microlayer. There is the added complexity with the discharge of very hydrophobic substances such as oil and grease from galleys since these substances would naturally rise to the surface and concentrate there unless they were adequately dispersed or emulsified by the discharge and mixing processes. To determine the actual magnitude of the interface concentration process in an area where large numbers of cruise ships pass regularly would take a very carefully designed study with great care taken on the selection of reference or control sites. For the moment, however, the Panel looks to the dilution studies and the Whole Effluent Toxicity tests (WET) reported in Sections I, and Appendix 8, which show little to nil likely impact from discharge from a moving vessel.

There is also concern regarding contaminants from the wastewater discharges from small cruise/tourism vessels, which take groups of passengers into the bays and fjords for recreational activities, and wildlife/scenery viewing. If small vessels are at anchor in these calmer environments, there is more potential for accumulation of contaminants in the buoyant freshwater layers that could accumulate at the seawater surface interface. However, the loading of contaminants from these small vessels is relatively small. The impact of small cruise ship discharge in fjords and embayments requires further study.

References:

Albright, L.J. 1980. Photosynthetic Activities of Phytoneuston and Phytoplankton. Can. J. Microbiol. 26: 389-392.

Bell, C.R., and L.J. Albright. 1982. Bacteriological Investigation of the Neuston and Plankton in the Fraser River Estuary, British Columbia. Est., Coastal & Shelf Sci. 15: 385-394.

Bidleman T.F. and C.E. Olney. 1974. Chlorinated Hydrocarbons in the Sargasso Sea Atmosphere and Surface Water. Science 183: 516-518.

Boehm, P.D. 1980. Evidence of the Decoupling of Dissolved, Particulate and Surface Microlayer Hydrocarbons in the Northwestern Atlantic Continental Shelf Water. Mar. Chem. 9: 255-281.

Colonell, J.M. et al. 2000. Cruise Ship Wastewater Discharge into Alaskan Coastal Waters. Alaska Sealife Center, Tech. Report No. 2000-01, 48 p.

Cross, N.J. et al. 1987. Contaminant Concentrations and Toxicity of Sea-water Microlayer Near Los Angeles, California. Mar. Environ. Res. 23: 307-323.

De Souza Lima, Y. and M.J. Chretiennot-Dinet. 1984. Measurements of Biomass and Activity of Neustonic Microorganisms. Est., Coastal and Shelf Sci. 19: 167-180.

Dietz, A.S. et al. 1976. Heterotrophic Activities of Bacterioneuston and Bacterioplankton. Can. J. Microbiol. 22: 1699-1709.

Dragcevic, D.J. and V. Pravdic. 1981. Properties of the Seawater-Air Interface 2. Rates of Surface Film Formation Under Steady State Conditions. Limnol. Oceanogr. 26: 492-499.

Duce, R.A. et al. 1972. Enrichment of Heavy Metals and Organic Compounds in the Surface Microlayer of Narragansett Bay, Rhode Island. Science 176: 161-163.

EPA. 2002. Cruise Ship Plume Tracking Survey. Report Office of Water, Office of Wetlands, Oceans and Watersheds. EPA 842-R-02-001.

Hardy, J.T. et al. 1977. Occurrence of Hydrocarbons in the Surface Film, Sub-surface Water and Sediment in the Waters Around the United Kingdom. Rapp. P. Reun. Cons. Int. Explor. Mer. 171: 61-65.

Hardy, J.T. et al. 1985. Sea-surface Microlayer Metals Enrichment in an Urban and Rural Bay. Est., Coastal and Shelf Sci. 20: 299-312.

Hardy, J.T. 1987a. The Sea-surface Microlayer of Puget Sound: Part I. Toxic Effects on Fish Eggs and Larvae. Mar. Environ. Res. 23: 227-249.

Hardy, J.T. 1987b. The Sea-surface Microlayer of Puget Sound: Part II. Concentrations of Contaminants and Relation to Toxicity. Mar. Environ. Res. 23: 251-271.

Hardy, J.T. et al. 1990. Aquatic Surface Microlayer Contamination in Chesapeake Bay. Mar. Chem. 28: 333-351.

Holland, L. E. 1986. Effects of barge traffic on distribution and survival of ichthyoplankton and small fishes in the Upper Mississippi River. Transactions of the American Fisheries Society 115: 162-165.

Hunter, K.A. 1980. Processes Affecting Particulate Trace Metals in the Sea Surface Microlayer. Mar. Chem. 9: 49-70.

Kieber, D.J., J. McDaniel and K. Mopper. 1989. Photochemical Sources of Biological Substrates in Seawater. Implications for Carbon Cycling. Nature 341: 637-639.

Killgore, K.J., S.T. Maynord, M.D. Chan and R.P. Morgan II. 2001. Evaluation of propeller-induced mortality on early life stages of selected fish species. North American Journal of Fisheries Management 21:947-955.

Killgore, K.J., A.C. Miller and K.C. Conley. 1987. Effects of turbulence on yolk-sac larvae of paddlefish. Transactions of the American Fisheries Society 116:670-673.

Larson, R.A. and M.R. Berenbaum. 1988. Environmental Phototoxicity. Environ. Sci. and Technol. 22: 354-360.

Maki, J.S. 1993. The Air-Water Interface as an Extreme Environment. Chapter 16, 409-439. In T.E. Ford (ed.) Aquatic Microbiology: An Ecological Approach. Blackwell Scientific Publications, London, England.

Marty, J.C. and A. Saliot. 1976. Hydrocarbons (Normal Alkanes) in the Surface Microlayer of Seawater. Deep-Sea Res. 23: 863-873.

Mora, S., S. Demers and M. Vernet (eds.) 2000. The Effects of UV Radiation in the Marine Environment. Cambridge University Press, Cambridge, UK.

Morgan, R.P. II, R.E. Ulanowicz, V.J. Rasin, Jr., L.A. Noe and G.B. Gray. 1976. Effects of shear on eggs and larvae of striped bass, *Morone saxatilis,* and white perch, *M. americanus*. Transactions of the American Fisheries Society 105:149-153.

Piotrowicz, S.R. et al. 1972. Trace Metal Enrichment in the Sea-surface Microlayer. J. Geophys. Res. 77: 5243-5254.

Seba, D.B. and E.F. Corcoran. 1969. Surface Slicks as Concentrators of Pesticides in the Marine Environment. Pest. Monit. J. 3: 109-193.

Vernet, M. 2000. Effects of UV Radiation on the Physiology and Ecology of Marine Phytoplankton Chapter 9 pp 237-278. In S. Mora et al. (eds.) The Effects of UV Radiation in the Marine Environment, Cambridge University Press, Cambridge, UK.

Wade, T.L. and J.G. Quinn. 1975. Hydrocarbons in the Sargasso Sea Surface Microlayer. Mar. Pollut. Bull. 6: 54-57.

Wetzel, R.G. 2001. Limnology: Lake and River Ecosystems 3rd edition Academic Press, New York NY. 1006 p.

Wanderschneider, K. 1979. Vertical Distribution of Phytoplankton During Investigations of a Natural Surface Film. Mar. Biol. 52: 105-111.

Williams, P.M. et al. 1980. *In situ* Measurements of Sea-surface Film Potentials. J. Mar. Res. 38: 193-204.

Williams P.M. et al. 1986. Chemical and Microbiological Studies of Sea-surface Films in the Southern Gulf of California and off the West Coast of Baja California. Mar. Chem. 19: 17-98.

Zagarese, H.E. and C.E. Williamson. 2000. Impact of Solar UV Radiation on Zooplankton and Fish. Chapter 10, pp. 279-309 In S. Mora et al. (eds.) The Effects of UV Radiation in the Marine Environment, Cambridge University Press, Cambridge, UK.

Zaitsev, Yu.P. 1970. Marine Neustonology Akad. Nauk. Ukrainskoi. SSR, Naukova Dumka, Kiev 207 p. (Translat. Into English, Programs for Scientific Translation, Jerusalem, 1971).

Zhou, X. and K. Mopper. 1997. Photochemical Production of Low Molecular Weight Carbonyl Compounds in Seawater and Surface Microlayer and their Air-Sea Exchange. Mar. Chem. 56: 201-214.

Section VII

Criteria for Delineating Areas Potentially Sensitive to Cruise Ship Wastewater Discharges

C-J Beegle-Krause, Alan Mearns, Lincoln Loehr, Kenwyn George, and Carolyn Morehouse

The Panel has attempted to answer the following questions:

"Are there waters and nearby shorelines that might be more sensitive than other areas to cruise ship discharges? So much more sensitive that discharging should be restricted?"

Two approaches need to be considered: sensitive areas and sensitive species. A *sensitive area* with respect to wastewater discharge is simply any area where concentrations of contaminants are likely to exceed water, sediment or seafood quality criteria, guidelines or public expectations. A *sensitive species* is either:

Sensitive to wastewater (finding wastewater toxic), or

A species that bioaccumulates wastewater compounds or microorganisms and when consumed passes contaminants up the food chain or transmits an infection.

The following is a summary list of considerations:

Location
Oceanography
Species
Timing

At this time we will leave out species that might be affected by any ship moving through the water (e.g. fish larva damaged when pulled through the propeller circulation, or injured on impact with the vessel).

Designating areas as more or less sensitive to a particular type of pollutant is similar to the concept of the NOAA Environmental Sensitivity Index (ESI), which classifies different shoreline areas and local resources by their sensitivity to oil. The key difference here is that we are considering areas in open water, where the water is likely to be moving due to winds and tides, and the discharge is very likely to disperse. Dumping coffee grounds on the same place on a beach above the tide line day after day will lead to a large pile of coffee grounds, but dumping a cup of coffee into the coastal water in the exact same place day after day is very unlikely to leave a trace. We are also considering sensitive species rather than land types. So sensitive areas for cruise ship discharges will have some fundamental differences from sensitive shorelines.

The premise is that we can define locations in both time and space where discharges may cause a high enough exposure potential (concentration multiplied by time) for harm that action should be taken. Time must be considered because the pollutants do not affect the water itself. Rather, it is

the living things that live in the water and the animals further up the food web that depend on those local resources that are potentially affected. The degree of impact depends on what a particular organism is exposed to, for how long, and at what dose. Both the water and resources are potentially moving through a particular area at particular times, which limits contaminant exposure.

The simplest consideration is of things that are of interest to humans and that do not change locations – confined or sessile species that are planned for human use and consumption. Fish pens and harvested shellfish beds fall into this category. Shellfish and other sessile or confined consumable bioaccumulators need to be protected from repeated contact with contaminants.

Other animals may have life stages that are particularly sensitive to contact with certain contaminants. These animals may be resident in the area or migrating through the area (such as young salmon heading to sea). Areas where sensitive creatures move through an area could lead to temporary closures to discharges. Sensitive life stages of animal ubiquitous in the area would not cause the same restrictions since the population is so large.

A particular concern of many people is the potential impact of ship wastewater discharge on humpback whales (*Megaptera novaeangliae*). The Panel reviewed available research and current knowledge with a view towards a particular area – Icy Strait – a water body frequented by humpback whales and cruise ships. Current knowledge would seem to indicate that humpback whales are not affected by cruise ship wastewater if the ships follow the recommended discharge practice (discharge at minimum speed of 6 knots, 1 nautical mile from shore).

Oceanographic phenomena play a key role in moving water and thus moving the contaminants. In quiet fjords, large residence times due to small tidal exchange would need to be considered. A pollutant could potentially build up in the surface waters or when deeper waters are renewed infrequently.

Given these considerations, the Panel has three recommendations for cruise ship discharges:

Stationary discharge in a low tidal exchange area could lead to water quality issues and should be avoided.

The current requirements for large cruise ships – wastewater discharge at a minimum speed of 6 knots and at least 1 nautical mile from shore – are good management practices and should be practiced by all passenger ships.

No discharges should occur within 0.5 nautical mile of commercial bivalve shellfish beds[33].

[33] Prohibiting discharges within 0.5 mile of shellfish beds aids the protection of human health. Because there are many chemicals, (e.g. drugs and endocrine disrupters) and possibly viruses discharged in all effluents, including those from advanced treatment systems, the panel recommends minimizing these elements from reaching shellfish that could be consumed by humans. Ships at a distance of 0.5 miles or more will most probably be under way, and the effluents will experience considerable dilution. A vessel closer than this, especially if at anchor, should hold their waste if possible until under way and further offshore. In-port discharge (allowed for small cruise ships and

The Panel has two recommendations for identifying sensitive areas:

1. At this time, the Panel is not aware of any species that has both a sensitive life stage and a population that is limited to an area where cruise ships discharge wastewaters. (Ubiquitous species are not considered for sensitive area delineation). However, should such a species be identified it could be an important issue for cruise ship discharge timing in a particular location.

2. Areas where long residence time or minimal neap tidal exchange[34] occurs are areas where chemicals from wastewater discharges are a potential issue. Tidal exchange information could be used to prioritize areas for further study to determine whether or not wastewater discharge is a problem.

large cruise ships that meet stringent effluent standards) should not be a concern with regard to shellfish. Shellfish harvest for human consumption near ports is not recommended and often prohibited, since bacteria sources are numerous.

[34] Neap tides occur just after the first and third quarters of the lunar month. At these times the difference between high and low tides is the smallest. Thus, water movement due to tide flux is the smallest. The Panel recognizes that "minimal neap tidal exchange" must be more precisely defined before it can be used as a criterion for establishing no-discharge zones.

Section VIII

Sources of Shipboard Chemicals and Pathways by which They Could Reach the Marine Environment

Michael Watson and Alan Mearns

Summary

Between May 2000 and September 2002, members of the Science Panel attempted to develop a good working knowledge of the likely "universe of chemicals" brought on board and used on large cruise ships. They visited several ships – spending two days underway on one– and conducted extensive interviews with corporate managers, officers and crew. Eight possible pathways that onboard chemicals could be discharged to the environment were identified and evaluated. It is the conclusion of the authors that a properly maintained, well-managed, modern cruise ship, operating in full compliance with government regulations, will not release shipboard chemicals into the environment at a quantity or level that will cause measurable negative environmental impact. The authors suggest several chemicals for future monitoring for the purposes of validating best practice or dilution models.

Introduction

The issue of completely understanding and verifying the full extent and nature of chemicals on board cruise vessels is no simple matter. Cruise vessels – as floating, self-propelled, self-contained huge hotels which travel through, and to, a vastly differing series of marine environments - utilize a myriad of different chemical compounds as part of their daily operations. These include the same basic spectrum of chemical materials typically associated with, for example, large resort hotels. But with cruise vessels, additional varieties of chemicals and chemical waste products are associated with - and produced by - the need for motorized propulsion of these modern techno-behemoths through the sea. Another important factor is the innate need to constantly protect the vessel's exposed surfaces against corrosion, biofouling organisms, and similar damaging factors not typically found in the case of land-based tourist facilities of the same types and sizes.

In view of this complex set of factors, it is first necessary to solidify estimations of off-vessel contaminant transport with a good working knowledge of the likely universe of chemicals, which might occur on a typical vessel such as this in the first place. This we shall hereafter refer to as the "likely chemical inventory" on such vessels, which is meant to be more or less synonymous with terms like "source", or "sink" for the chemicals utilized, brought, or generated aboard ship.

Two of the more important and obvious mechanisms by which chemicals stored, used, generated, or otherwise associated with these vessels (i.e., the "likely chemical inventory") can reach the marine environment are of course, the graywater and blackwater routes (exposure pathways) of direct discharge into the sea. Eco-risk and the likelihood of environmental loading from these two obvious and deliberate discharge pathways can then be estimated or predicted with the help of dispersion modeling, and the various mixing calculations, which are set forth in Section I in greater detail[35].

However, graywater and blackwater are by no means the only two pathways by which shipboard chemicals can reach the surrounding marine environment. Chemicals associated with such vessels can reach the sea (and in some cases the air as well) via such other routes as bilge water, incineration of certain wastes, offloading of hazardous wastes for special disposal, and accidental spillage or leakage. Chemicals present in hull paints and anti-fouling coatings can also reach the sea from simple electrolysis and diffusion. Trace amounts of hazardous substances (but more typically in this case, potentially invasive organisms) can also be transported from far-off regions by the uptake and exchange of ballast water. There are thus many possible mechanisms – both major and minor - by which chemicals associated with large multi-use vessels with their several thousands of passengers and crew can reach the surrounding environment. And although graywater and blackwater are probably paramount in terms of exposure routes, they are only two of several important pathways that need to be considered in the case of "chemicals from cruise vessels".

In their recent petition to the US EPA, in which 54 environmental organizations initiated an ongoing national EPA review of impacts of cruise ship pollution, the Blue Water Network (2000) identified five main exposure pathways by which extraneous materials coming from cruise ships can impact the marine environment. These pathways were:

1. Sewage (black water),
2. Gray water,
3. Hazardous wastes,
4. Solid wastes, and
5. Oily bilge water.

After examining a few representative vessels first hand, and learning as much as possible about the general issue of chemicals used, associated with, and generated from cruise ships, the Panel reached many of the same conclusions about possible sources, pathways and their relative importance as did the authors of the original Blue Water Network Report. The Panel thus tends to concur in principle with this general scheme. However, we also propose three additional exposure "pathways" by which chemicals associated with cruise vessels could conceivably reach and impact the surrounding marine environment. The three additional pathways are:

6. Incineration (air),

[35] For the purposes of this section the dispersion scenario often used will suffice. For a large cruise ship discharging at a rate of 200 cubic meters per hour (considered an average maximum rate of discharge for a large cruise ship) and traveling at the minimum allowed speed of 6 knots, the mixing will be greater than 50,000 to 1.

7. Ballast water, and
8. Vessel coatings.

For purposes of this report, these eight basic "pathways" will also in varying degrees of importance be assumed to continuously interrelate with and contribute to the primary sources (the likely chemical universe) of chemicals associated with large "typical" cruise vessels, as well as serving as the key routes by which various chemicals might be transported from the vessel into the surrounding environment.

The Panel notes that the cruise ship industry is aware of these pathways as well. The International Council of Cruise Lines (ICCL) has recently instituted a number of mandatory (must comply to maintain ICCL membership) practices to enhance recycling, waste minimization, substitution of hazardous chemicals with less hazardous chemicals, zero-discharge for certain wastes, and pursuit of best available technology (ICCL 2001).

Potentially Hazardous Chemicals (General Shipboard Universe of Chemicals)

Potentially hazardous chemicals that could come from large cruise vessels are made up of many subcategories. Those of importance include such chemical products and by-products as:

Dry Cleaning fluids: Most commonly used, and of most concern in this group is the very common dry cleaning fluid tetrachloroethylene, also known as perchloroethylene; PERC. At least one major cruise ship line, Holland-America Lines (HAL) has recently taken steps to begin eliminating PERC in its laundry facilities, in order to minimize possible impacts on both health and environment. Because PERC is rapidly volatized, it is not persistent or highly bioaccumulative in the marine environment. (Note: Precautions and safe work practice must be observed to ensure individuals are not overexposed to vapors.) Spills of this material could at least briefly result in adverse aquatic /ecological impact at sensitive or critical receptor site(s).

The 2000 Environmental Report for HAL indicates that they have added closed-loop charging systems to their dry cleaning machines, in order to allow increased employee safety, greater control and chemical management, and reduced consumption of PERC. This procedure will reduce PERC vapors during machine charging. Also in place are filtration systems, which remove PERC from dry cleaning process condensate on HAL's Celebrity Class ships. HAL's target for 2001 was to evaluate alternative non-PERC dry-cleaning systems. Likely replacement for PERC is the use of CO_2 technology. Equipment for this type of dry cleaning process has been recently modified for the maritime environment and installed on at least one of HAL's large vessels. The CO_2 system will continue to be evaluated by HAL in the coming year.

Other Degreasing fluids /cleaning fluids (engine room, etc): Our visits to assess stocks and types of chemicals aboard cruise ships have revealed relatively large quantities of various degreasing and cleaning compounds used in areas where propulsion and engine-related work is performed. These areas are also at and around the lowermost levels or bilge. The exact chemical composition(s) of these degreasing fluids is difficult to accurately assess. Usually, only the "Trade Name" of the product is displayed on the label. However, relatively large amounts were

noted, in 5-gallon drums and larger, on several ships. Further identification of these fluids, their use, and the likelihood of their getting from a waste stream to the ocean (e.g., bilge pathway,) is recommended.

We are not yet certain of the actual importance of degreaser compounds as potential environmental pollutants. However, as described elsewhere in this document, we have noted that the use of metal degreasers is both necessary and very important for machinery. Fairly large quantities of liquid degreasing materials are commonplace on the vessels. Identifying the various chemical ingredients making up these degreasing products can be elusive-- especially fleet wide or on smaller vessels-- because "trade names" are often used in record keeping and other manifest documents. In the past, many such degreasing compounds were primarily trichloroethylene (TCE)-based. In recent years in most modern countries, the widespread use of TCE for this purpose has been severely cut back, because of health and environmental concerns about this chemical. The Panel notes that wastewater sampling and analysis in 2000-2002 has not detected the presence of TCE in cruise ship wastewater.

Most of the rather large quantities of degreasers used on the vessels we have visited carry trade names such as "Enviroclean", in either 25-liter pails, or 210-liter drums. It would appear likely that on the more modern and environmentally aware vessels these materials no longer contain TCE or similarly chlorinated ethylenes or ethanes as active ingredients. But at the moment, we know nothing at all – other than seeing the trade names on the labels - about what they actually contain.

Other Cleaning materials: Large vessels like these typically have extensive interior and exterior "brightwork", which involves extensive use of brass, chrome, glass and other materials which require rigorous daily effort in cleaning and polishing to maintain a lustrous and proper appearance. Like large hotels, extensive square footage of carpets and staterooms need to be cleaned and shampooed on a frequent basis. A variety of common cleaning chemicals, brighteners and polishes are used aboard ship to accomplish these tasks. Except for the necessity of having more need for polishes and sealants to help protecting exterior ship surfaces against the corrosive effects of being continually at sea, the types of chemical products in question do appear to not differ significantly from those used in a typical hotel on land.

Pesticides: From our visits to the representative large cruise vessels thus far, extensive or even occasional use of pesticides which would unduly persist in the environment does not seem to be practiced. Review of the available records for lines like Holland America have revealed that most, perhaps all, of the "insecticides" used on board are in fact those which are pyrethroid based, thus (under reasonable situations of use and management) posing only a minimal to nil amount of potentially significant environmental harm and environmental persistence. This, plus the fact that no "priority" pesticides like DDT, or other environmentally undesirable organochlorine pesticides have ever been detected in any of the samples taken from Alaska cruise vessels during the past three years of State led or mandated monitoring, makes it unlikely in our view that pesticides currently used aboard reasonable and responsible cruise vessels are likely to pose significant problems to the surrounding aquatic environment.

One particular pesticide of modern times – chlorpyrifos – is of routine concern to ecotoxicologists and others who assess potential chemical impacts to the environment. Although chlorpyrifos is apparently not used at all on the cruise vessels we have visited, its high-moderate toxicity and its ability to persist for several weeks in aquatic environments makes it probably the single most important type of "modern" or "recent" insecticide in terms of potential ecosystem impacts. For this reason, we recommend that chlorpyrifos be specifically targeted as a chemical we routinely inquire about, in future assessments of the types and amounts of pesticides used on such large vessels for various situations requiring insect control.

Photo lab: The photo labs on large vessels are not unlike photo labs on land. They utilize significant quantities of developer, stop bath, fixer solution, etc. We have no detailed information about specific quantities of chemicals used in photo labs, but what we have learned from our visits and the available literature does indicate that the major cruise lines do strive to keep these products properly and safely stored and utilized. Waste materials from these labs are normally treated as hazardous waste, and offloaded in compliance with hazardous waste requirements. It would seem unlikely that under normal situations these materials can exit the vessel and cause ecosystem harm. ADEC and the Coast Guard routinely and randomly sample wastewater for silver, a key component of photo lab chemicals. To date these agencies have not found concentrations that would lead them to suspect dumping of photo lab chemicals into the wastewater pathway.

Medical Lab/Infirmary: From what we have observed first hand from visiting representative vessels of Holland America and Royal Caribbean Cruise Lines, most modern cruise vessels will have a small but modern and well-equipped medical laboratory and infirmary on board. These facilities contain the usual small but necessary core repertoire of medications, and some basic small stocks of necessary reagents and solvents. They are stored in compliance with regulations, and do not appear likely to enter waste streams or exposure pathways in any significant ways which could impact the marine environment.

Printers: Holland-America Lines indicate that fleet-wide, the use of printing plates which require chemical printing solution have been replaced with water-based printing plates. Other cruise lines are following similar practices (ICCL 2001).

Spent explosives: These are used occasionally in small quantities for celebratory (theatrical productions, parties, etc) and /or emergency (e.g., lifeboat flares) purposes, according to the environmental report we have been furnished by HAL. They are treated as hazardous waste.

Fluorescent ballast/Batteries/Butane Lighters: According to HAL environmental report of 2000, these three materials are specifically targeted on board as hazardous waste materials, and separated out from all other waste streams. Specially trained employees individually sort all materials coming from such places as kitchen and food, passenger cabins, and common waste areas. The three materials are combined together, and handled as special hazardous waste. They are then offloaded for appropriate landfill disposal in Vancouver, by a private contractor. We

assume that other cruise lines do the same thing, but have no way of substantiating this at this time other than recognizing the mandatory practices set forth by ICCL.

Miscellaneous: In food serving areas, HAL indicates that the use of Sterno as a warming fuel for chafing dishes has been replaced fleet wide with a compound called "ecofuel", which contains no alcohol, is odorless, cleaner burning, and is not considered an air pollutant. It also has a lower flash point and is housed in spill-resistant containers. We do not know the precise chemical identity of this "ecofuel" at this time.

Pharmaceuticals, personal care products, fragrance materials and other emerging contaminants in water; including "other organic wastewater contaminants" (OWCs) typically associated with discharge from POTWs:

Some of the larger cruise vessels can carry as many as 3000+ passengers and crew at any given time. These individuals, like the rest of the general population who utilize land- based sewage systems and publicly owned treatment works (POTWs)-- bring aboard, utilize, shed, metabolize and /or excrete a wide variety of pharmaceuticals. A good example of these is the general category of anti-hypertensive drugs, which are taken by a significant portion of the middle aged and elderly in our society of today. Such medications are typically metabolized in the body to various other more polar (more water soluble) compounds or chemical groups, and excreted as residues in urine and feces, thus entering (mostly) into the blackwater pathway from the vessels. Various other drugs and medications such as antibiotics and steroids can either be taken orally or applied topically to the skin, in which case they either enter the blackwater pathway as metabolites via excreta, or go to the gray water pathway via washoff from showers and sinks.

Recent well-publicized findings of very low concentrations (maximum levels were less than one part per billion (ppb), and more typically only a few parts per trillion (ppt)) of various pharmaceuticals, other personal care products, and hormonal residues in river water resources by the US geological Survey (Kolpin et al, 2000; Barnes, et al, 2002; and others (Daughton and Ternes, 1999; Velagaleti et al, 2002) have raised the issue of whether or not these materials would likely be of consequence as components of (e.g., via gray water pathway) discharges from cruise ships into the marine environment. In a 2002 report from the USGS, in which samples were taken in water bodies partially fed either by wastewater from treatment plants, or runoff from confined animal feeding areas (CAFO's; stockyards) the thirty most frequently detected individual compounds found at trace (parts per trillion) levels belonged to the following general groups:

1. Steroids (89% frequency of detection)
   coprostanol (common marker found in sewage); is a sterol which originates in the mammalian gut, and is thus a good marker for enteric sources of pollution.
2. Nonprescription drugs (81%)
3. Insect repellant (DEET) (74%)

4. Detergent metabolites (69%)
   4-nonylphenol in particular is a common breakdown product from detergents
5. Disinfectants (66%)
   triclosan, is a good example of a frequently noted chemical arising from the use of various antibacterial soaps and lotions
6. Plasticizers (64%)
   Important residues originating from "plastics include the phthalate acid esters, such as diethyl-hexyl phthalate DEHP, and di-n-butylphthalate (DNBP), which are frequently noted at trace levels in the environment, worldwide.
7. Fire retardants (60%)
8. Antibiotics(48%)
9. Insecticides (45%)
10. PAHs (44%)
11. Reproductive hormones (40%)
12. Other prescription drugs (32%)
13. Antioxidants (29%)
14. Fragrances (27%)
15. Solvent (24%)

For a good overview of current research efforts at identifying and ranking the very broad and diverse universe of various pharmaceuticals and other compounds associated with waste water discharges, it is worth noting that the U.S. Geological Survey (USGS) is currently developing methodology for a list of some 95 "new" target compounds which have been recently identified as part of the USGS "National Reconnaissance of Emerging Contaminants in U.S. Streams". Their list of compounds – a few of which (e.g., PAHs) are already regarded as "Priority Pollutants" in water – includes the following categories:

1. Veterinary and Human Antibiotics: N=22

   Tetracyclines (e.g., chlortetracycline, N=4),
   Fluoroquinones (e.g., ciproflaxicin, N=4),
   Macrolides (e.g., erythromycin, N=3)
   Sulfonamides (e.g., Sulfamethoxazole, N=7)
   Others (Lincomycin, etc. N=4)

2. Human Drugs (prescription): N=13

   Metformin (antidiabetic agent), Cimetidine, Ranitidine (antacids)
   Enalaprilat, Diltiazem (antihypertensives), Digoxin, Digoxigenin (cardiac care)
   Fluoxetine, Paroxetine (antidepressants), Warfarin (anticoagulant)
   Salbutamol (antiasthmatic), Gemfibrozil (antihyperlipidemic)
   Dehydronifedipine (antianginal metabolite)

3. Human Drugs (non-prescription): N=6

   Acetominophen (analgesic), Ibuprophen (anti-inflammatory, analgesic)
   Codeine (analgesic), Caffeine (stimulant), 1,7,dimethylxanthine (caffeine metabolite)

Cotinine (nicotine metabolite)

4. Industrial and Household Wastewater Products: N=39

- Insecticides: N=8

  Chlorpyrifos, Diazinon, Methyl parathion
  cis-Chlordane, Lindane, Dieldrin
  Carbaryl
  N,N-diethyltoluamide (DEET)

- Plasticizers: N=5

  bis(2-Ethylhexylphthalate, Diethylphthalate
  bis(2-Ethylhexyl)adipate
  Ethanol-2-butoxy-phosphate, Triphenylphosphate

- Detergent Metabolites: N=5

  p-Nonylphenol
  Nonylphenol monoethoxylate (NPE01), Nonylphenol diethoxylate

- (NPE02)

  Octylphenol monoethoxylate (OPE01), Octylphenol diethoxylate (OPE02)

- Fire Retardants: N=2

  Tri(2-chloroethyl)phosphate
  Tri(dichloroisopropyl)phosphate

- Polycyclic Aromatic Hydrocarbons (PAH; fossil fuel and combustion indicators): N=6

  Naphthalene, Phenanthrene, Anthracene
  Fluoranthene, Pyrene, Benzo(a)pyrene

- Antioxidants: N=5

  2,6-di-tert-Butylphenol
  Butylatedhydroxyanisole (BHA), Butylatedhydroxytoluene (BHT)
  5-Methyl-1H-benzotriazole, 2,6-di-tert-Butyl-p-benzoquinone

- Others: N=8

  Tetrachloroethylene (PERC) (solvent), Phenol (disinfectant)
  1,4-dichlorobenzene (fumigant), p-Cresol (wood preservative)
  Triclosan (antimicrobial disinfectant)
  Acetophenone (fragrance)
  Phthalic anhydride (used in plastics), Bisphenol A (used in polymers)

5. Sex and Steroidal Hormones: N=15

- Biogenics: N=7

17b-Estradiol, 17a-Estradiol, Estrone, Estriol
Testosterone, cis-Androsterone
Progesterone

- Pharmaceuticals: N=5

  17a-Ethynylestradiol, Mestranol, 19-Norethisterone (ovulation inhibitors)
  Equilenin, Equilin (hormone replacement therapy agents)

- Sterols: N=3

  Cholesterol (fecal indicator)
  3b-Coprostanol (carnivore fecal indicator)
  Stigmastanol (plant sterol)

Fragrance Materials (FMs) as a specific class of emerging trace contaminants:

Simonich et al (2002) report that the primary route of FMs into the environment is via consumer products discharged down the drain to municipal wastewater systems. From the various USGS studies cited above, fragrances or FMs made up a relatively low 27 per cent of the various types of pharmaceutical and personal care types of ingredients detected in various wastewaters sampled in the USGS (2002) survey. However, this structurally diverse class of compounds is definitely an emerging group of chemicals, which merits attention. In recent years several investigators have reported detections of trace quantities of some of these FM compounds and their metabolites in both surface waters and aquatic organisms (Simonich et al, 2000). Simonich and her colleagues indicate that the more common specific types of FMs detected to date in wastewater most commonly belong to the following four groups:

1. nitromusks (e.g., musk xylene; (1-(1,1-dimethyl)-3,5-dimethyl-2,4,6-trinitrobenzene)
2. musk ketone (3,5-dinitro-2,6-dimethyl-4-tert-butylacetophenone)
3. polycyclic musks(e.g.,AHTN;7-acetyl-1,1,3,4,4,6-hexamethyl-1,2,3,4-tetrahydronaphthalene)
4. HHCB (1,3,4,6,7,8-hexahydro-4,6,6,7,8,8-hexamethylcyclopenta-[gamma]-2-benzopyran)

For other recent summaries about emerging "non-priority pollutant" contaminants in water see the U.S. Geological Survey Website, describing its efforts at monitoring emerging contaminants in U.S streams: http://toxics.usgs.gov/regional/emc.html

From the information presented and summarized at various points in this segment, it is evident that generally speaking, the most frequently detected groups of such "non-traditional pollutants" now being found in waters impacted directly from sewage runoff are steroids, nonprescription drugs, insect repellant (DEET), and detergent metabolites. In terms of highest concentrations noted in most studies of POTW wastes, detergent metabolites, steroids and plasticizers were the three categories that stood out from the others. Fragrance materials (FMs) and certain of the other of the other emerging target compounds being examined by the USGS and other researchers may also reveal other future examples of personal care products/pharmaceuticals which merit future attention.

Whether or not these heretofore mostly ignored, emerging chemical residues; or so-called "non-priority pollutants", are of importance to marine ecosystems is not known. However in view of the very low (ppt) levels typically noted for these various OWCs, pharmaceuticals, and similar "new" pollutants in receiving waters located below fixed and continuous land based point sources, and the tremendous dilution factors which apply to the comparatively low volumes of gray water and blackwater discharge, the Panel is quite doubtful that impacts of these chemicals in the case of cruise vessels are significant. Certainly cruise ships–despite their size and their need to process and clear wastes containing these various OWC / human-derived chemicals--will produce neither the continuous discharges nor the much greater volumes /quantities of such chemicals that are already entering riverine and near shore ecosystems from sewage, POTWs, and other land-based waste treatment facilities. In other words, compared to POTWs on a mass-balance basis, the contributions of these chemicals to the environment by cruise ships has to be relatively minor in extent.

Review of the eight exposure pathways by which onboard chemicals could reach the surrounding environment

1. Sewage & Graywater:

The past three years of sampling and analysis indicate that blackwater (sewage) and graywater (shower, sink, and galley water) are remarkably similar in water quality. Both have been shown to have (1) high levels of fecal coliform and suspended solids, (2) no measured hazardous substances, and (3) somewhat elevated concentrations of trace metals (copper, zinc) and plasticizers. Therefore these waste streams will be considered together. (bit of a tangent) Any product or chemical that is water soluble or capable of being suspended in the wastewater can be discharged overboard, and to those products we will limit our discussion.

As a general rule, large cruise ships generate 18 liters (5 gallons) of treated blackwater per person per day and 180 liters (50 gallons) of graywater per person per day. The volume of graywater and treated blackwater generated and discharged varies considerably from ship to ship and region to region. Much of the variation depends on the treatment process employed. However, looking at daily water consumption can give a general idea of the wastewater produced. Of the 25 large ships operating in Alaska in 2002, the Alaska Department of Environmental Conservation estimated the combined daily generation of graywater and treated blackwater was 567 m^3/ship (~150,000 US gallons) or 240 liters per person on board. Three years of sampling and analysis have not indicated vessels are using this pathway as a source of hazardous waste disposal. Elevated concentrations of copper, zinc and plastiziers have been detected. These levels, in general, are above marine water quality criteria but mirror the concentrations found in residential tap water. Recent whole effluent toxicity tests of graywater and blackwater effluent indicate little if any synergistic toxicity from wastewater constituents (Appendix 8). That, coupled with the minimum 50,000 to 1 mixing ratio estimated by the Panel in Section I, would seem to indicate that the wastewater pathway is not a significant one.

2. Hazardous wastes:

From what we understand from our various on-site observations while onboard large cruise vessels, and from discussions with Holland- America Lines, the hazardous waste pathway most likely will consist of materials which have been already discussed to some extent in the prior section on "sources" (likely chemical inventory).

Holland America Lines specifically identifies and deals with a special category of hazardous wastes (which they designate "Special Waste") which includes fluorescent ballast, batteries and butane lighters, as well as discarded and expired chemicals, medical wastes, explosives, rags /debris /fuel filters, dry cleaning wastes, photo wastes, spent paints and thinners. Holland America Lines indicates that on its vessels, these specific wastes are sorted by hand, from other waste streams on board. They are then pooled together as special hazardous waste to be off-loaded for land filling by "approved" hazardous material private contractors in Vancouver, B.C., which they indicate is one of just fifteen ports world-wide where special wastes are sanctioned for offloading for handling and disposal by qualified people. The 2000 Environmental Report from Holland- America Lines indicates that the quantities of special wastes generated by their entire fleet of 11 vessels, per week, are:

Batteries, 75 lbs;
Discarded and expired chemicals, 1735 lbs;
Medical Waste, 45 lbs;
Fluorescent lights, 153 lbs;
Explosives (e.g., from signal flares, theatrical productions), 6 lbs;
Rags /debris /fuel filters, 78 gallons;
Photo wastes, 2262 gallons;
Spent paints and thinners, 213 gallons

3. Solid Wastes:

Dunnage: The term "dunnage refers to materials which are used for packaging products, for transportation or storage, and is makes up a relatively large portion of the waste generated by cruise vessels. Dunnage includes primarily paper and plastic, and (at least in the case of Holland America Lines, and presumably large cruise vessels in general) is either incinerated on board (paper, cardboard), or landed for recycling or disposal. Holland America Lines indicates that their vessels land or incinerate approximately 30 cubic meters of non-hazardous paper and plastic, per ship per week.

Plastic types of containers, wrappings, and similar polymers like styrofoam (polystyrenes, etc) are ubiquitous in their use in modern society. As a consequence, low levels of phthalate acid esters (e.g., di-n-butyl phthalate, Di-(2-ethylhexyl phthalate), and similar materials used in common everyday plastics such as bread wrappers) are now routinely detected in various environmental media, as a mark of our industrialized society. Indeed, elevated levels of phthalates have been detected in gray and black water discharge.

Detected 2001 phthalates for large ships (µg/L)
(Geometric Mean)
From Table II-6, Section II

Bis(2-ethylhexyl)phthalate	butylbenzylphthalate	Diethylphthalate
6.510	0.357	5.913

In an effort to significantly reduce the plastic components in its dunnage, Holland America has recently (in 2000) eliminated the more than 5 million individually packaged containers of shampoo and hair conditioners used annually in its passenger staterooms, and replaced them with refillable bulk dispensers. To quote from Holland America Lines' 2000 Environmental Report: "...The company makes a significant effort in trying to eliminate packaging before products are even brought to our ships. In some cases, disposable packaging has been replaced with reusable cartons that are emptied and returned to the supplier for recycling and reuse. In other cases, plastic wrapping materials have been replaced with paper and wood that can be reused or incinerated. Cardboard, particularly cartons and packaging, is bundled for recycling in certain ports. Plastic pails, from items such as laundry soap, are cleaned and landed or reused onboard ships..."

Glass and Cans: These solid wastes include such items as aluminum soft drink cans, glass bottles, and tin cans from the galley. Holland America Lines indicates that after these materials are sorted and collected on board from their various waste streams, all glass is crushed, held in cold storage rooms, and regularly brought to land for recycling. The Panel observed these facilities and operations on several vessels. We observed that aluminum is separated from other metals; all cans and other metal containers are then crushed, and landed for recycling as well. According to Holland America Lines, one class of vessels (as an example) will land some 6000 pounds of crushed glass, and 450 pounds of compacted aluminum cans per vessel per week.

Food Wastes (see also Incineration Pathway): Large cruise vessels typically house several specialized restaurants and cafes. Disposing of food wastes is a major segment of their waste management. Using the waste management practices of HollandAmerica Lines as a typical example, food wastes are first initially separated and sorted in the galley areas. Paper and plastic (see comments on dunnage) are removed, and sent to different receptacles. Wet foods are then pooled and sent to large garbage- disposal units on board ("pulpers"), which grind up the wastes and remove the aqueous portion. This "waste water" then is recycled through the food slurry line and discharged as gray water (see also gray water pathway). The remaining dried food wastes are then incinerated on board. Holland America Lines estimates that each of their vessels generates about 12 cubic meters of food waste each week.

4. Oily bilge water and oily sludge:

Oily bilge water: The pathway of oily bilge water is a significant source of chemicals aboard cruise vessels. Whether or not this pathway allows significant transport from the vessel to the surrounding ocean depends on the efficiency of the vessel in processing its liquid bilge

contaminants (removing oil and associated sludge), and the level of compliance with MARPOL regulations and Alaska water quality standards, which require that bilge water be reduced to less than 15 parts per million (ppm) oil, leaving no visible sheen, and discharged only outside the 12 mile limit from land.

Bilge is a general term for the lowest part of the vessel. The bilge area thus becomes a natural repository for water and various other liquid materials, from sources such as the engines and propulsion system, and other mechanical and operational sources. As such, bilge water is normally a mixture of not only water, but also various oily fluids, mechanical lubricants and cleaning fluids and similar liquid wastes which can collect via gravity at this lowest point. According to the waste management practices we have seen on visits to Holland America Lines - that we assume to be typical - the bilge fluids are periodically pumped dry, and processed to remove contaminants of concern. Most of the concern and regulations about bilge water is due to its oil content. Separation and removal of the oil to comply with the allowable limit of 15 ppm presumably also results in the removal or minimization of other hydrophobic hazardous wastes like degreasing fluids, and other fluid materials associated with the propulsion system. It is our understanding that although treated oily bilge water below the 15 ppm level of compliance for oil may be discharged at sea outside the 12 mile limit, it is also under some circumstances offloaded for processing at approved shoreside treatment facilities. According to Holland America Lines 2000 Environmental Report, all of their cruise vessels now contain equipment capable of cleaning bilge water to less than 5 ppm oil.

Oily sludge: According to Holland America Lines documents, and substantiated by our on-board site visits to large cruise vessels, oily sludge material is first filtered from the bilge water, using a series of sludge tanks. Holland America indicates that in this process, waste oils, greases, lubricants and fuel filtering sludge coming from various shipboard operations and sources are separated out and subsequently routed on to the sludge tanks. It is our understanding that both international and US requirements forbid the ocean discharge of this oily sludge. It must be landed for disposal. In most countries, including the USA, no further treatment of the landed sludge is currently required. In most situations it is presumably taken to a landfill for disposal. However in its 2000 Environmental Report, Holland- America Lines indicates that all sludge from its vessels is recycled after landing, by approved waste contractors. Holland- America Lines' oily sludge material is recycled as a fuel source for such purposes as factory heating, energy production, and in some situations is refined for re-use.

Holland America Lines estimates that the amount of oily water recycled per ship, per week ranges from a minimum of 2 metric tons[36] to a maximum of 30 metric tons. The amount of oily sludge recycled for landing–per ship per week–averages about 5.6 metric tons, and ranges from a minimum of 4.7 metric tons to a maximum of 9 metric tons.

[36] 1 metric ton (tonne) of water = 1000 liters or 264 gallons

5. Incineration (Air-Water):

As highlighted elsewhere in other sections, incineration of waste materials, particularly dried food wastes and dunnage, is a common and efficient way to reduce the very large quantities of wastes generated aboard large cruise vessels carrying several thousand people over long distances at sea. Under most situations, incineration is a reasonable method of handling appropriate wastes, with a relatively low degree of potential offsite pollution. From the large body of information about incineration at land- based facilities we know that under certain situations (especially inadequate temperature and inadequate dwell-time) – incineration of certain hazardous materials can result in the formation of highly toxic and bioaccumulative compounds such as dibenzo-p-furans and dibenzo-p dioxins. However, from what the Panel has learned about cruise ship incineration practices in general, we do not regard the generation and/or atmospheric/oceanic exchange of these types of hazardous chemicals to be a factor of importance for large cruise vessels. Cruise ships employing reasonable practices appear to be mindful of the necessity to screen all potential materials prior to allowing them to be incinerated. According to the Environmental Report (2000) for Holland-America Lines, for example, materials like batteries (cadmium, mercury, nickel, etc.), electronic parts, and butane lighters are removed by workers prior to entering the incineration waste stream, and handled as special hazardous waste to be landed, or recycled off-ship. In addition, large cruise ships do not operate incinerators in port and, thus only underway.

Ash: The endpoint waste of all shipboard incineration is ash. Provided that the raw materials for incineration have been adequately screened for potential toxicity as described above, the ash generated in such a process should be unlikely to pose appreciable risks to health or environment. According to Holland- America Lines, both USA and international law allow for ocean discharge of ash, as long as it takes place outside the 12-mile limit. In the case of Holland- America Lines, their 2000 Environmental Report indicates that the bulk of their incinerator ash is landed and disposed by approved shoreside waste contractors.

Waste management information provided to the Panel by Holland- America Lines, indicates that an average of 1 bag (1,100 pounds) of ash is landed, per ship, per week. Weekly minimum per vessel is 0.5 bag (550 lbs.), with a maximum of 2 bags (2,200 lbs.) per vessel, per week.

6. Ballast Water:

Ballast water is used for ship stability. Tanks along the keel of the ship, usually called the double bottoms, when filled with liquid lower the center of gravity and improve the ride of the vessel. Double bottoms are usually dedicated for fuel, ballast or, increasingly in Alaska, wastewater. Typically, as fuel oil is consumed from one tank, ballast water is taken on in the dedicated ballast tanks to maintain the desired stability. Fuel tanks and ballast tanks are not interchangeable; otherwise oily water could be illegally discharged. Ballast and wastewater tanks may be interchangeable, if the vessel follows regulations and laws for proper wastewater discharge. Ballast water taken on board while a ship is in another part of the world and discharged in North America can be a mechanism for introducing unwanted and invasive

organisms. The U.S. Coast Guard is now finalizing a national ballast water policy to prevent the introduction of foreign aquatic species into coastal and internal waters of the United States. For now, cruise ships voluntarily change out ballast water well out to sea during their positioning voyages to the Pacific Northwest from other parts of the world. Thus, for ships operating between Vancouver, BC and Alaska, North Pacific ballast water is exchanged with North Pacific ballast water.

7. Vessel coatings:

Underwater hull coating systems typically include a base anticorrosive coating (AC) covered by an antifouling (AF) coating. If the AC is not damaged or otherwise exposed to the seawater, it will not leach. The anti-fouling coat serves to inhibit marine growth on the hull. Marine fouling is undesirable because it increases drag and fuel consumption, while decreasing vessel speed.

Most large cruise ship hulls are steel. Hulls of smaller vessels, including some small cruise ships, and some specialty vessels (e.g., tenders and lifeboats) are often constructed of aluminum or fiberglass sheathing. The coating system applied will vary with the hull material. For instance, steel, fiberglass, and wood hulls are typically coated with copper-based coatings, and aluminum hulls with tributyltin (TBT) or biocide-free silicone-based coatings.

AF topcoats control biological growth by ablating and/or releasing antifouling agents into the surrounding water. This release is gradual and continuous. Since most hulls use copper-based coatings; copper and zinc (another biocide commonly found in antifouling paints) are the most common releases. Those aluminum-hulled vessels with TBT-containing coatings will release TBT and small amounts of zinc, and may release copper, depending on the TBT coating formulation. (EPA, 1999) Only slow release TBT coatings are allowed on vessels in Alaska per Alaska Statute 46.03.715]

Zinc bars welded to steel hulls as sacrificial anodes for cathodic protection are also obvious sources of zinc.

Well-maintained large cruise ships, with their small hull surface area in proportion to persons carried, are not a significant source of antifoulants. Due to the lack of adequate maintenance and high vessel traffic, marinas often have elevated levels of antifoulants. Stallard et al. (1987) noted that the sediments of nearly every California marina tested had high concentration of butyltins. Marina sites in North Carolina had significantly higher levels of arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc than did reference sites (NCDEM, 1991). McMahon (1989) found significantly higher concentrations of copper, lead, zinc, and mercury in the sediments at a marina site than in the parent waterbody.

Suggestions for Monitoring Current-Use and "New" Chemicals

The Panel suggests that the following chemicals be added to the list of current chemicals monitored by the State of Alaska. If after one season's monitoring they are found to be non-occurring in the gray water or blackwater pathway, then they could be discontinued. Note:

1. Contaminants:

Measure for chlorpyrifos and other new-generation pesticides, cosmetics, fragrances, drugs and fire retardants for environmental impacts and their presence in landside point source discharges which in turn might indicate a need for cruise ship monitoring. In this regard, Alaska should coordinate the research of other states and federal agencies in accessing the significance of the use of these materials and their impact. Selective monitoring in effluents, sediments and mussels would be a natural outcome. Note: This is not targeted at cruise ships. It is a program of adaptive environmental management.

2. Mass Balance Markers:

Coprostanol (fecal sterol) and caffeine, and /or its metabolite 1,7-dimethylxanthine, though not toxic, would be good markers for mass balance study to underscore and verify the dilution models and confirm that materials from wastewaters are not cumulative in coastal waters, sediments or shellfish (such as mussels).

References

Barnes, K.K., D.W. Kolpin, M.T. Meyer, E.M. Thurman, E.T. Furlong, S.D. Zaugg, and L.B. Barber, 2002. Water-quality data for pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000. USGS Open-File Report 02-94. 7 pp. U.S. Geological Survey, Information Services, Bldg. 810, Federal Center, Box 25286, Boulder, CO , USA 80255.

Blue Water Network. 2000. March 17, 2000 letter to US EPA Administrator. Available at www.bluewaternetwork.org

Daughton, C.G. and T.A. Ternes, 1999. Pharmaceuticals and personal care products in the environment: agents of subtle change? Environmental Health Perspectives 107: Suppl. 6, p 907-938. December.

EPA. April 199. Uniform National Discharge Standards for Vessels of the Armed Forces. EPA-821-R-99-001. p.457

Kolpin, D.W., E.T. Furlong, M.T. Meyer, E.M. Thurman, S.D. Zaugg, L.B. Barber, and H.T. Buxton, 2002. Pharmaceuticals, hormones, and other organic wastewater contaminants in U.S. streams, 1999-2000: a national reconnaissance. Environmental Science and Technology 36: (6), p 1202-1211.

ICCL. 2001. ICCL INDUSTRY STANDARD E-01-01 (Revision 1) *CRUISE INDUSTRY WASTE MANAGEMENT PRACTICES AND PROCEDURES.* http://www.iccl.org/policies/environmentalstandards.pdf

McMahon, P.J.T. 1989. The Impact of Marinas on Water Quality. *Water Science Technology*, 21(2):39-43.

NCDEM. 1991. *Coastal Marinas: Field Survey of Contaminants and Literature Review*. North Carolina Division of Environmental Management, Raleigh, NC. Report No. 91-03.

Simonich, S.L., W.M.Begley, G. Debaere, and W.S. Eckhoff, 2000. Trace analysis of fragrance materials in wastewater and treated wastewater. Environmental Science and Technology 34:(6), 959-965.

Simonich, S.L., T.W. Federle, W.S. Eckhoff, A. Rottiers, S. Webb, D. Sabaliunas, and W. DeWolf, 2002. Removal of fragrance materials during U.S. and European wastewater treatment. Environmental Science and Technology 36:(13), 2839-2847.

Stallard, M., V. Hodge, and E.D. Goldberg. 1987. TBT in California Coastal Waters: Monitoring and Assessment. *Environmental Monitoring and Assessment,* 9:195-220. D. Reidel Publishing Company.

Velagaleti, R., P.K. Burns, M. Gill, and J. Prothro, 2002. Impact of current good manufacturing practices and emission regulations and guidances on the discharge of pharmaceutical chemicals into the environment from manufacturing, use, and disposal. Environmental Health Perspectives 110: (3). P213 - 220. March.

Section IX

Small Commercial Passenger Vessels

Carolyn Morehouse

Summary

Small ships are defined as having 50-249 overnight passengers. These ships discharge continuously, including at anchor and in port. Because they discharge continuously, it is difficult, if not impossible, to obtain a representative sample. Small ships are sampled in port, when passengers are not normally on board.

Small ships collect graywater in small tanks and then discharge using a pump or discharge the graywater directly from drains to the ambient water. Some ships manage graywater using a combination of both practices. The graywater management practice depends on ship configuration. Most small ships do not have space for wastewater holding tanks. Black water is treated in Marine Sanitation Devices (MSD) before discharge. The Alaska Marine Highway System (AMHS) ferries and two small passenger ships mix their graywater and blackwater and treat both effluents with their MSD.

The majority of small ships' travel in Alaska is concentrated in the southeast, however one small ship operates in Prince William Sound and two small vessels operate in the Aleutians and Bering Sea for less than 20 days per season.

To put the quantity of wastewater discharged from small cruise ships in perspective, one can compare the volume from small ships to that from large cruise ships. Large and small cruise ships and ferries discharge approximately 559,802 m^3 (147,704,923 gallons) of wastewater annually in Alaskan waters[37]. Of this total, small cruise ships and ferries discharge an estimated 33,666 m^3 (8,882,860 gallons), roughly 6% of the total annual cruise ship and ferry wastewater discharge.

Sampling and analysis of small ship graywater and treated blackwater in 2000 and 2001 found high concentrations of fecal coliform and total suspended solids on most ships (Section II).

Sample results from the biological treatment systems show that these treatment systems, as currently operated on board small ships, do not meet effluent standards for bacteria and suspended solids.

The macerator/chlorinating system when used on small ships has demonstrated an ability to treat wastewater to meet fecal coliform bacteria and total suspended solids standards. However, this is achieved by the use of high levels of chlorine. Chlorine is an effective disinfectant but excessive chlorine residual is toxic to marine life. A standard should be set for residual chlorine to prevent excessive chlorine from entering the marine environment.

[37] This number is based on Vessel Specific Sampling Plans received by the DEC in 2000, 2001, and 2002.

Section I discusses the significant mixing and dispersion of wastewater discharged from a moving vessel. Small ships, with the exception of one "larger" small ship, discharge blackwater automatically when treatment is complete. Graywater is usually not treated and is discharged directly to an overboard port. When small ships discharge at anchor or in port, the wastewater is not diluted with ambient water by dynamic mixing that occurs when underway. The Panel therefore, recommends that wastewater discharge from small ships should be avoided at the head of fjords, bays, and other areas of low net marine water outflow (Sections VI, VII).

ADEC hired a contractor to perform a risk screen to determine if the discharge from small ships presents an ecological or human health risk. The results of this risk screen should be completed in January 2003 and will be available on the ADEC cruise ship website.[38]

Background

In 2001, the Alaska legislature passed a law to regulate cruise ship and ferry wastewater discharges to Alaska marine waters. The law applied to ships with 50 or more lower berths. Cruise ships are divided into two classifications, small cruise ships with accommodations for 50-249 overnight passengers and large cruise ships with accommodations for 250 or more overnight passengers. Five of the Alaska Marine Highway System (AMHS) ferries are defined as small ships under Alaska law.

The state law regulates two types of wastewater: blackwater and graywater. Blackwater originates from ship's toilets. Graywater is water produced from showers, sinks and laundry. Graywater comes from three main sources: (1) galley or kitchen areas, (2) passenger/crew accommodations, and (3) laundry facilities.

The 2001 law set fecal coliform and TSS effluent discharge limits for both gray and blackwater for large ships but delayed compliance for small ships until January 1, 2004. The law requires ADEC to submit a report that addresses adverse impacts on human health and the environment from small ship discharges to the Governor by December 2002.

Operation

Small ships do not have the same per person water usage as large vessels. Large vessels are more water intensive because they do laundry up to 20 hours per day, produce food and cleanup 24-hours per day. The volume of gray water on a large cruise ship is 50 gallons per day (gpd) per passenger, whereas on a small cruise ship it is 25 gpd per passenger. The per passenger gray water discharge for the AMHS ferries is even less than 25 gpd. The AMHS ferries' passenger number varies with the season because more passengers travel during the summer. In addition, few ferry passengers are on the ship for extended periods of time and consequently not all ferry passengers use the shower or galley facilities. Passenger black water production is the same on large and small cruise ships, however most small ships use seawater for flushing rather than fresh water. The average flow rate from a small ship ranges from 2.5 to 5.0 gallons/minute for both gray and black water, with a peak around 45 gallons/minute for short periods.

[38] http://www.state.ak.us/dec/cruise.htm

Small ships have more flexibility with their itinerary than large ships. Large ships mainly travel from port to port and to Glacier Bay or another glaciated fjord, whereas small ships can anchor in smaller coves. Some small ships leave Juneau and do not visit another port until they arrive back in Juneau many days later.

The dilution white paper (Section I) concluded that there is little environmental effect from wastewater discharges that occur while a vessel is traveling at least 6 knots and is one mile from shore. This is due to the large volume of water displaced by the hull and the mixing action from the propellers. Small ships, with exception of three large small ships that have holding tank capacity, discharge automatically. When the treatment system is complete, the wastewater effluent is discharged. Discharges that occur while the vessel is tied up in port or at anchor are not mitigated by dilution.

Some small ships provide kayak tours from the vessels. If the vessel is discharging above the waterline while the kayaks are around the boat, there is the potential for human contact with fecal coliform bacteria and other microorganisms either from the port or effluent in the near-surface ambient water.

Cruise ships and ferries are required by law to track their wastewater discharge locations. Most large ships comply by keeping a log that includes the time and latitude and longitude where the discharge began and ended. This method of tracking a discharge event works reasonably well for large cruise ships that have discrete discharge events. However, for small cruise ships and ferries that discharge continuously, the operators could only state the vessel route and the times and dates that the vessel was anchored. They also estimated the volume of wastewater produced based on the number of passengers and crew. (See Table IX- 1 and Table IX- 2 for typical number of passengers and crew per vessel.)

Table IX-1: Small Cruise Ship Facts

Ship Name	**Approximate Length (feet)**	**Maximum number of passengers and crew**	**Maximum amount Black water Produced (gallon/day) includes seawater for flushing**	**Maximum amount of Graywater Produced (gallon)/day**
Wilderness Adventure	100	96	480	2400
Wilderness Discoverer	110	120	600	3000
Sea Bird	150	96	480	2400
Sea Lion	150	102	510	2550
Clipper Odyssey	200	204	1020	5100
Yorktown Clipper	200	200	1000	10000
Hanseatic	400	320	1600	16000

Ship Name	Approximate Length (feet)	Maximum number of passengers and crew	Maximum amount Black water Produced (gallon/day) includes seawater for flushing	Maximum amount of Graywater Produced (gallon)/day
Spirit of Oceanus	295	178	890	8900
Spirit of Discovery	166	105	525	2625
Spirit of '98	192	122	610	4880
Spirit of Columbia	143	99	495	2475
Spirit of Alaska	110	95	475	2375
Spirit of Endeavour	217	130	650	3250

Table IX-2: AMHS Ferry Facts

Ship Name	Approximate Length (feet)	Maximum Number of passengers and crew	Maximum Amount Black water Produced (gallon/day) includes seawater for flushing	Maximum Amount of Graywater Produced (gallon)/day
Taku	300	412	1030	4120
Columbia	350	566	1415	5660
Malaspina	350	550	1375	5500
Matanuska	250	548	1370	5480
Kennicott	400	790	1975	7900

Maps were created from the 2001 discharge and route information provided by the small cruise ships. (See Figures IX-1 and IX-2.) The maps cover the peak month of July. The maps were created from the vessel itineraries using a fair amount of interpretation. Assumptions are listed in the metadata for the geographical information system (GIS) map. The maps are therefore intended to provide general information regarding small vessel movements and discharge quantities and are not an exact tool.

Small ships visit the following places:

- Elfin Cove, Chichagof Island
- Hoonah, Chichagof Island
- Glacier Bay
- Excursion Inlet
- Skagway
- Haines
- Juneau
- Tracy Arm Bar
- Inside Endicott Arm (Sanford Cove)
- Gambier Bay, Admiralty Island
- Warm Springs Bay, Baranof Inland
- Red Bluff, Baranof Island
- Wrangell
- Petersburg
- Misty Fjords
- Sitka
- Baranof Warm Springs
- College Fjord
- Columbia Bay
- Cordova
- Metlakatla
- Petersburg
- Prince Rupert
- Sergius Narrows
- Seymour Narrows
- Whittier
- Thomas Bay
- Victoria, B.C.

Figure IX-1 Small Passenger Vessel Discharge Events

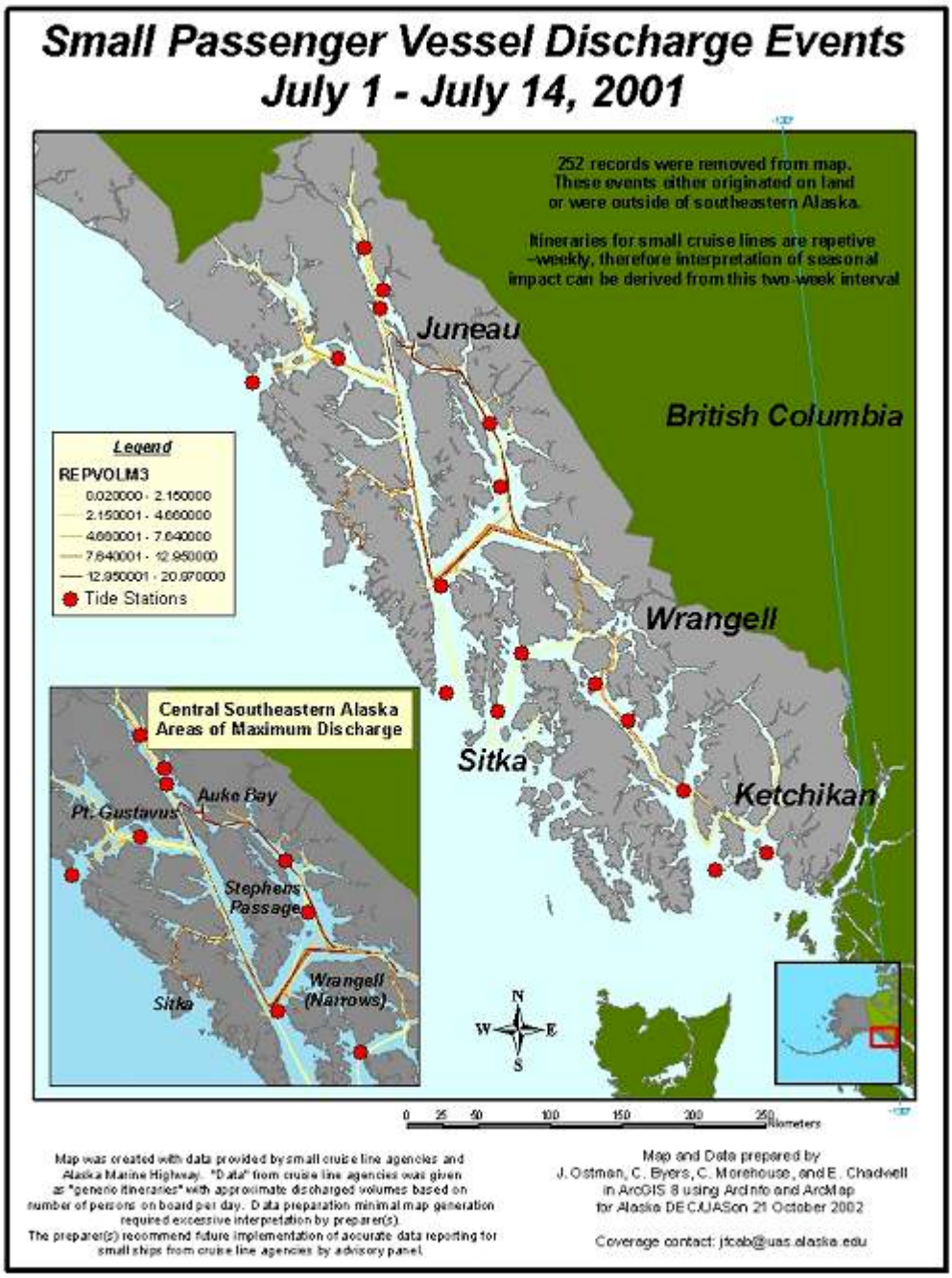
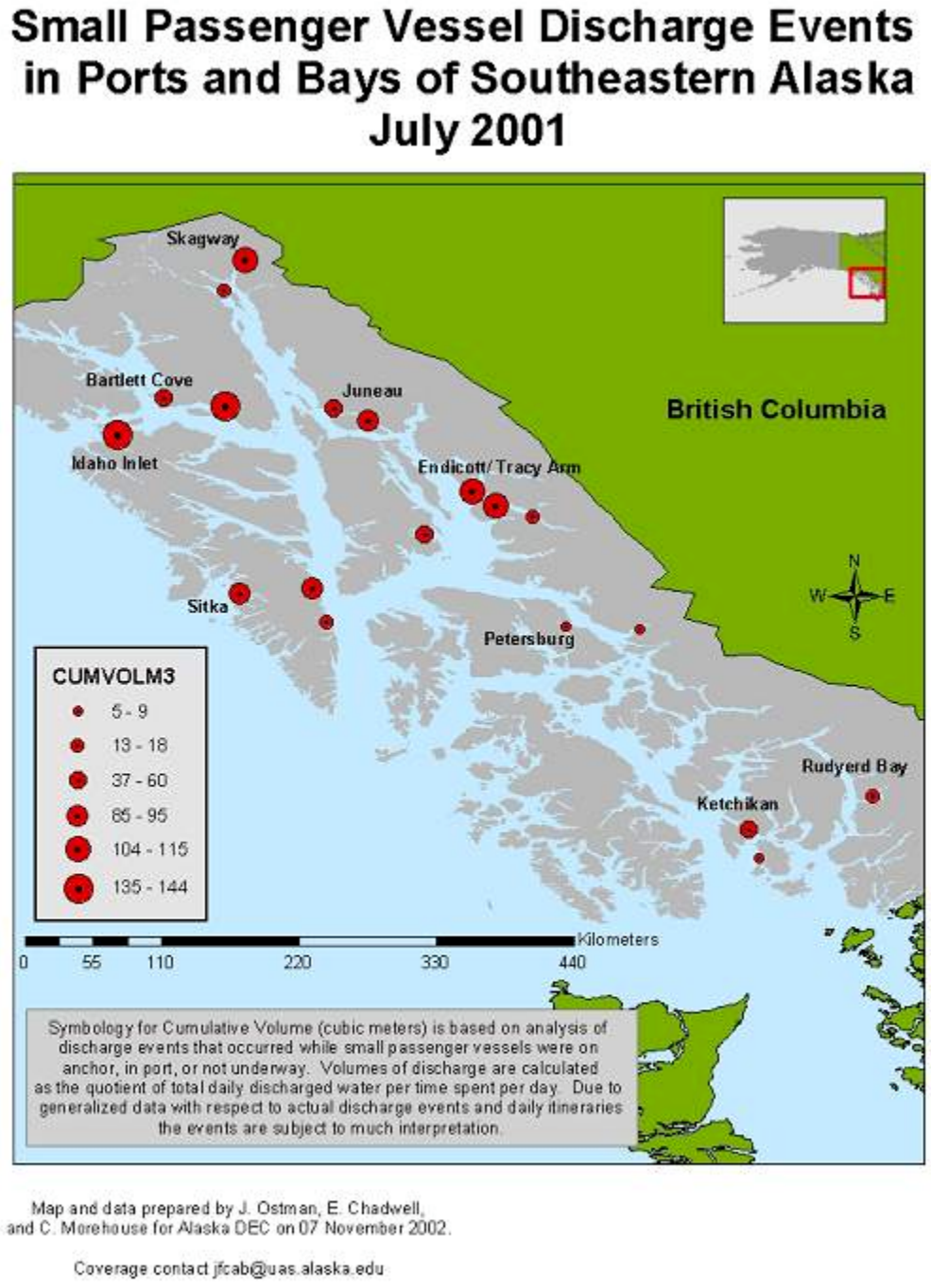


Figure IX-2 Small Passenger Vessel Discharge Events in Ports and Bays of SE AK



Treatment Systems

The AMHS ferries and two small passenger ships mix their gray and blackwater before

treating the combined flows with their macerator/chlorinator MSD.

Some small ships treat graywater by adding chlorine to the discharge line or holding tank. Chlorine is effective for disinfecting, however excessive chlorine residual is toxic to marine life.

Small ships collect graywater in tanks and then discharge using a pump or discharge the graywater by gravity to the ambient water. Some ships manage graywater using a combination of both practices. Graywater management practices depend on the ship's configuration. Most small ships do not have wastewater holding tanks.

Individual ship's treatment systems are listed in Table IX- 3. All small ships treat blackwater in a USCG approved Type II Marine Sanitation Device (MSD). Most small ships operating in Alaska treat sewage using a macerator/chlorinator system, except for the two largest of the small ships that treat sewage with biological systems.

The macerator/chlorinator system treats waste using a macerator pump to cut and break up solids. Sodium hypochloride is produced by electrolysis of the seawater and is used for disinfection. The volume of seawater used is up to 10 times the volume of wastewater.

There are several shortcomings with the macerator/chlorinator system. One operator experienced failure of the macerator pumps used to break up the solids. The pump manufacturers claimed that the pumps were not being operated and maintained according to their specifications. Regardless of the reason for pump failure, the solids were not sufficiently broken up and the system failed. The sampling program provides a check to ensure that systems are functioning properly.

Sometimes, when in estuaries or other marine waters that have low salinity, small ships need to add salt tablets to ensure there is enough salt to produce chlorine. Some vessels have been adding liquid chemical sodium hypochloride (bleach) to supplement the limited amount of chlorine produced by the electrochemical cell in low saline waters.

Table IX-3. Small Commercial Passenger Vessel Wastewater Treatment

Small Vessel Operator	**Small Vessel Name**	**Discharging Graywater (GW) within Alaska?**	**Discharging Blackwater (BW) within Alaska?**	**Wastewater Treatment System Type******	**Comments**
Alaska Marine Highway System	*Columbia*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Alaska Marine Highway System	*Kennicott*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Alaska Marine Highway System	*Malaspina*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Alaska Marine Highway System	*Matanuska*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Alaska Marine Highway System	*Taku*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Clipper Cruise Lines	*Clipper Odyssey*	Yes	Yes		Graywater treated with Chorine
Clipper Cruise Lines	*Yorktown Clipper*	Yes	Yes	Macerator/ Electrocatalytic	Graywater treated with Chlorine
CruiseWest	*Spirit of 98*	Yes	Yes	Biological/Chemical	No graywater treatment
CruiseWest	*Spirit of Columbia*	Yes	Yes	Macerator/ Electrochemical	No graywater treatment
CruiseWest	*Spirit of Discovery*	Yes	Yes	Biological / Chemical	No graywater treatment
CruiseWest	*Spirit of Endeavor*	Yes	Yes	Macerator/chlorinator	No graywater treatment
CruiseWest	*Spirit of Oceanus*	Yes	Yes	Biological & Chemical	No graywater treatment
Glacier Bay Tours	*Wilderness Adventurer*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Glacier Bay Tours	*Wilderness Discoverer*	Yes	Yes	Macerator/chlorinator	Treats BW & GW
Hapag-Lloyd	*Hanseatic*	No	No	Biological/ Chlorination	No graywater treatment
Lindblad Expeditions	*Sea Bird*	Yes	Yes	Macerator/chlorinator	Graywater treated with Chlorine
Lindblad Expeditions	*Sea Lion*	Yes	Yes	Macerator/chlorinator	Graywater treated with Chlorine
Seabourn Cruise Lines	*Seabourn Spirit*	No	No	Biological & Chemical	No graywater treatment
Society Expeditions	*World Discoverer*	Yes	Yes	Unknown	

**** Treats both black and gray water in the MSD unless indicated in the comments

Sampling

Comparison Of Treatment System Success

Macerator/chlorinator

In April 2002, the Alaska Marine Highway System (AMHS) discovered that their wastewater samples had been collected at a point in the treatment process prior to chlorination. Samples taken after May 1, 2002 were collected after chlorination. Table IX- 4 shows that samples taken **before** May 1, 2002 have a fecal coliform geometric mean of **5,740 fecal colonies** per 100 ml of water (MPN/100ml). Samples taken **after** May 1, 2002 have a geometric mean of **3.4 MPN/100 ml fecal colonies** per 100 ml of water (MPN/100ml). This comparison also shows that those samples collected in the proper location have a slightly lower biological oxygen demand (BOD), lower chemical oxygen demand (COD) and higher chlorine residual.

Table IX-4: Alaska Marine Highway System: Summary Geometric Mean for Conventional Pollutants

Time	Number of samples	Test	Ammonia	pH	BOD	COD	TSS	Total Cl2	Free Cl2	Fecal Coliform Bacteria	Conductivity
	n =		mg/l		mg/l	mg/l	mg/l	mg/l	mg/l	MPN/100ml	Umhos/cm
AMHS from 2000-April 2002	11	Geo	8.88	7.37	81.15	874.95	50.8	0.67	0.14	5,740	35,316.07
		Mean									
AMHS May 2002-Present	6	Geo	0.38	7.58	7.47	686.79	45.8	9.08	6.12	3.4	27,231.01
		Mean									

This data demonstrates that a properly operated macerator/chlorinator systems can meet the effluent standards of 200 fecal coliform colonies/100 ml and 150 mg/l of total suspended solids (TSS). A residual chlorine limit is needed, however, to prevent over-chlorination and its toxic effects to aquatic life.

Biological

Sample results from the five ships with biological systems show that this treatment system, as currently operated on board small ships, cannot meet effluent standards for bacteria and suspended solids. Those vessels, however, have holding tanks and could wait to discharge their wastewater until traveling at a minimum of 6 knots and more than 1 mile from shore, thereby benefiting from dilution and increased distance from shellfish consumed by humans.

Data Overview

A summary of small ship conventional pollutant data received by September 30, 2002 is contained in Table IX- 5. The limited laundry and galley wastewater sample data indicate low fecal coliform counts for these types of graywater. The laundry sample data collected from dedicated holding tanks shows few to no fecal coliform. The accommodation graywater samples also had few fecal coliforms.

The treated blackwater and the treated BW&GW mixed effluents had similar sample results, except for ammonia where the treated BW had much higher results. As one would expect, gray water treated with chlorine had fewer fecal coliform bacteria than untreated graywater, however it had higher BOD and COD. The higher COD could result from chlorine reactions. There were a greater number of untreated graywater versus treated graywater samples. The BOD results of the untreated graywater ranged from 2.79 to 1010 mg/l. Because there are more untreated graywater samples than treated graywater samples, the geometric mean of the BOD for untreated graywater samples is lower than the BOD of treated graywater samples. The treated gray water also had a higher TSS than untreated gray water. The cause of this result is unknown.

Table IX-5: Small Ships: Summary Geometric Mean for Conventional Pollutants

2001 and 2002 data

Wastewater Type	n =	Ammonia mg/l	pH	BOD mg/l	COD mg/l	TSS mg/l	Total Cl2 mg/l	FREE Cl2 mg/l	Fecal Coliform bacteria MPU/100ml	Conductivity Umhos/cm
Treated Blackwater	14	31.50	7.65	21.51	1004.25	97.57	0.30	0.15	1,546	37,400
BW&GW mixed & treated	19	1.34	7.25	58.08	930.01	61.14	1.12	0.38	1,414	31,653
Mixed Graywater (chlorine treated)	4	-	7.90	382.70	880.36	186.88	78.62	58.72	1,225	-
Mixed Graywater (untreated)	9	7.29	6.97	95.42	228.30	52.90	ND	ND	99,096	53
Graywater Accommodations	10	-	6.74	164.28	174.00	24.33	0.11	0.05	9	-
Graywater Laundry	2	0.25	9.13	123.21	319.00	21.45	0.35	0.18	2	-
Graywater Galley	2	-	-	247.40	-	42.63	2.21	-	50	-

ND = non detect

Dashes "-" indicate that a pollutant was not analyzed

Since the regulations were not in place in 2002, the small ships sampled only parameters listed in the law. Alkalinity, Ammonia as N, Oil & Grease, Conductivity, Total Kjeldahl Nitrogen (TKN), Phosphorous, Total Organic Carbon (TOC), and total settleable solids (TSS) data were **not** collected. The 2002 ADEC samples include these analyses.

The individual small ship conventional sample data are listed in the Tables IX-6 and IX-7. More discussion of these samples is included in Section II.

Table IX-6. Conventional Samples taken by ADEC

			AlkalinityTotal as CaCO3	Ammonia as N	BOD 5 Day	COD	Oil & Grease	Fecal Coliform MPN	Free Cl2	Conductivity	TKN	pH	Phosphorous, Total	Total Cl2	T OC	Total settleable solids	TSS
		MDL	**0.34**	**0.016**	**1.0**	**3.4**	**1.0**	**2**	**0.1**	**1.0**	**0.1**	**0.1**	**0.011**	**0.1**	**0.3**	**0.1**	**1.3**
Jul-20-02	Matanuska	BW&GW-MSD	79.5	1.27	134	451	27	1	10	23000	17.6	6.88	2.38	25	336	*0.05*	75.2
Jul-22-02	Columbia	BW&GW-MSD	166	29.4	117	495	30	22	12	22800	42.4	7.67	5.65	20	419	0.23	73.9
Jul-10-02	Kennicott	BW&GW-MSD	76.3	*0.0008*	*0.05*	870	*0.05*	1	25	31200	28.7	8.1	*0.0055*	40	274	*0.05*	22.5
Jul-9-02	Malaspina	MSD-1	62.3	0.121	*0.05*	514	13	1	2.5	23800	0.8	7.91	0.345	3.5	6	*0.05*	22.9
Sep-4-02	Spirit of Columbia **	TBW		21.4	146	700		200	*0.05*	NA		7.26		0.1			133
Jul-9-02	Spirit of Oceanus	BW&GW-MSD		21.1	870	1610		3000000	*0.05*	NA		5.26		0.25			295
Aug-22-02	Taku	BW&GW-MSD	148	10.7	177	780	37	5000	10	28200	48	8.33	4.92	15	186	23	311
Jul-13-02	York Clipper	TBW-MSD	116	6.32	5.47	512	8.5	2400	*0.05*	34500	5.7	7	2.33	0.05	299	*0.05*	66.6
Jul-13-02	York Clipper	GW	61	*0.0008*	138	228	52	1	*0.05*	369	0.4	8.19	0.856	0.05	352	*0.05*	17.1
		Min	**61**	**0.0008**	**0.05**	**228**	**0.05**	**1**	**0.05**	**369**	**0.4**	**5.26**	**0.0055**	**0.05**	**6**	**0.05**	**17.1**
		Max	**166**	**29.4**	**870**	**1610**	**52**	**3000000**	**25**	**34500**	**48**	**8.33**	**5.65**	**40**	**419**	**23**	**311**
		GeoMean	**94.2**	**0.8**	**20.6**	**601.1**	**9.8**	**81.5**	**0.9**	**14576**	**7.9**	**7.3**	**0.8**	**1.6**	**172.4**	**0.1**	**69.9**

**** Graywater sample not taken for this ship because no graywater was produced during the sampling period on board the ship.**

Table IX-7: Samples taken for ADEC by Industry

Date	Vessel Name	Water type	Ammonia Nitrogen	BOD 5 Day	COD	Fecal Coliform	Total Cl2	Free Cl2	pH	TSS
			mg/l	mg/l	mg/l	MPN	mg/l	mg/l		mg/l
		MDL	**0.016**	**1.0**	**3.4**	**2**	**0.1**	**0.1**	**0.1**	**1.3**
7/18/02	Sea Bird	TBW	23.5	105	461	4000	2.2	1.4	7.83	329
7/18/02	Sea Bird	GW	0.971	263	621	*1*	2.7	1.8	7.05	N/A
7/21/02	Sea Lion	TBW	10.9	335	767	30,000,000	*0.05*	*0.05*	8.01	801
7/21/02	Sea Lion	GW	0.752	364	678	*1*	*0.05*	*0.05*	7.32	56.3
8/4/02	Sea Lion	GW	1.48	536	1210	5000	*0.05*	*0.05*	6.26	250
8/4/02	Sea Lion	TBW	26.7	293	996	220000	0.1	*0.05*	6.2	486
7/6/02	Spirit of 98	GW	0.796	47.1	149	2	*0.05*	*0.05*	7.19	129
7/6/02	Spirit of 98	TBW	102	127	897	220	1.2	0.8	8.02	96.8
8/3/02	Spirit of 98	TBW	15.3	164	940	30,000	*0.05*	*0.05*	6.95	32.8
7/22/02	Spirit of Columbia	TBW	21.4	70.1	1020	10	0.2	*0.05*	7.3	76
8/5/02	Spirit of Columbia	TBW	21.4	146	700	200	0.1	*0.05*	7.26	133
7/18/02	Spirit of Discovery	TBW	77.2	112	949	5,000,000	*0.05*	*0.05*	7.16	333
7/18/02	Spirit of Discovery	GW	ND	35.4	44.2	60,000	0.22	0.14	7.17	94.2
7/11/02	Spirit of Endeavour	TBW	83.3	478	1400	16,000,000	*0.05*	*0.05*	7.48	657
7/11/02	Spirit of Endeavour	GW	0.691	450	927	16,000,000	*0.05*	*0.05*	10.1	0.691
7/17/02	Spirit of Oceanus	BW&GW	58.4	1060	1810	5,000,000	0.2	*0.05*	6.89	232
7/1/02	Wilderness Adventurer	BW&GW	74.2	175	614	140	2.0	1.0	8.21	238
7/3/02	Wilderness Discovery	BW&GW	52.4	643	1120	23	*0.05*	*0.05*	6.7	99
8/19/02	Wilderness Adventurer	BW&GW	39.2	174	931	2200000	2.1	1.1	8.16	155
	Wilderness Adventurer	BW&GW	42.4	163	800	500000	2.1	1.1	8.2	114
		Min	**0.008**	**35.4**	**44.2**	**1**	**0.05**	**0.05**	**6.2**	**0.65**
		Max	**102**	**1060**	**1810**	**30000000**	**2.7**	**1.8**	**10.1**	**801**
		Geo Mean	**9.7**	**203.8**	**701**	**8586**	**0.20**	**0.14**	**7.43**	**98.00**

ND= non detect

Representative Sampling

Small ships discharge in port but have a difficult time obtaining representative samples during in-port sampling. The ship's port time is spent disembarking passengers and getting ready for the next trip. There is usually little wastewater produced during this day in port.

To get a truly representative sample some vessels need to be sampled while underway. This was economically unfeasible in the 2001 and 2002 seasons when a third party was required to take the samples. Once a voyage has begun, small vessels often will not return to another port for days and it would be an economic hardship to leave quarters empty to accommodate the sampler. The Alaska "cruise ship program" regulations, effective November 15, 2002[39], will allow for vessel employees who meet particular qualifications to conduct wastewater sampling. This has the potential to increase the representativeness of small ship wastewater samples in the future.

It is also difficult to get a representative sample from some small vessels because of the ship's physical configuration. It is sometimes economically infeasible or physically impossible to sample every wastewater discharge line or get a composite of the different graywater types from the various discharge points.

Several of the 2002 wastewater samples from small ships were questionable and some were discarded. ADEC sampled the *Wilderness Discovery* on July 15, 2002. The sample line was at the tank bottom and the tank was low. It was concluded that the sample line was too low and the sample was sludge, so it was discarded.

Samples from the *Spirit of Columbia* (July 22, 2002) and *Spirit of 9*8 (August 3, 2002) were questionable and were not included in the table. The sample plans for these vessels call for samples to be taken as near as possible to the arrival time of the vessel. However, the samples were taken over 3 hours after the ship arrived.

The scheduled DEC sampling of the *Spirit of Columbia* on September 3, 2002 was terminated because the graywater looked atypical. The discharge line had a room number on it, and when the sampler asked to see the room, it was found that the crew had been running the shower. Although shower water is gray water, these samples are not representative of graywater discharges and will not be included in the statistical analysis.

[39] Link to regulations will be available on the ADEC Cruise Ship website: http://www.state.ak.us/dec/press/cruise/cruise.htm

Section X

Monitoring Contaminants in the Alaska Marine Environment

Alan Mearns, Michael Watson, and Ken Hall

Summary

Traces of organochlorine compounds (PCB's, pesticides), petroleum hydrocarbons, butyltin compounds (from antifouling paint) and trace elements (arsenic, copper, zinc, etc.) have been found in mussels sampled at five Alaska coastal sites by the National Status and Trends Program (NSTP) of the National Oceanic and Atmospheric Administration (NOAA). The sites, sampled biennially in the spring, include two in Southeast (Ketchikan and Skagway), two in Prince William Sound (Valdez and Unakwik Inlet) and Homer Spit, all adjacent to both commercial and non-commercial vessel traffic lanes. For most organic chemicals, concentrations in mussels from these sites have been much lower than in mussels elsewhere along the U.S. Pacific Coast (California, Oregon and Washington). Polycyclic aromatic hydrocarbons (PAH) are ten times lower than along the rest of the Pacific Coast and 100 to 1000 times lower than in mussels from urban bays of the West Coast. Several organochlorines, namely lindane-related compounds, are equal to or higher in mussels from Alaska than in those from further south along the U.S. west coast: this is probably due to the precipitation and snow-melt runoff of these compounds from global atmospheric sources. For trace metals, concentrations in Alaska mussels have been typical of expected "background" concentrations. A half dozen metals are higher in mussels from the least "urbanized" site, Unakwik Inlet, than from the more urbanized sites (Skagway, Ketchikan, Valdez, Homer). The metal lead (Pb) has been elevated in mussels from a site at Skagway, but is now approximating concentrations found elsewhere in Alaska. With the possible exception of mercury, there have been no longterm increases in contamination but some, such as PCB's and PAHs, have been decreasing in concentrations during the past decade or more; the slight increase in mercury is most notable at the least urbanized site (Unakwik Inlet).

Other data sources indicate that PAHs in mussels from marinas and boat harbors in Prince William Sound are as high or higher than in mussels from the West Coast urban bays.

Time and resources did not allow for analysis of data on contaminants in sediments or fish from these and other sites nor have we completed a review of historical data on contaminants in commercial fishes of Alaska from large-scale surveys conducted during the late 1960s through the 1970's.

Obviously, more data from Alaska coastal sites are needed, at the right time (summer), to determine if passenger vessel activity is a relevant contributor to coastal contamination, for example in remote tourist destinations such as Glacier Bay and Tracey Arm.

Environmental monitoring provides a check that regulatory actions have their intended benefit and reduces uncertainty that there are no surprises. Although it is important to note that the Panel believes cruise ships are not likely to contribute measurable contamination, an enhanced monitoring of contaminants in mussels and sediments in Southeast Alaska, Prince William Sound, along the Kenai Peninsula, and in Cook Inlet, during the tourist season, could provide a valuable tool in assuring that state coastal waters remain relatively uncontaminated.

Introduction

The final step in the Science Advisory Panel approach and framework is to determine if cruise ship activity is in fact leading to contamination of adjacent waters, sediment and resources.

This white paper uses limited data to help answer several questions:

1. What are concentrations of contaminants along the Alaskan coastline traversed by passenger vessels?
2. How does chemical contamination at these sites compare to elsewhere?
3. Are contaminant concentrations increasing, decreasing or remaining unchanged?
4. What, if any, additional monitoring needs to be done to make sure cruise ships and other sources are not contaminating Alaskan shorelines?

The information offered here presents a dilemma. A limited amount of contaminant monitoring has been underway along the Alaska coast, but it was not specifically designed to intercept contamination from passenger vessels, or distinguish vessels from other sources. It was designed to track regional trends, away from obvious chronic point sources. The dilemma is whether or not to use the information at all: if contamination was found, what was the source? And if contamination was not found, does that mean there is none?

Ironically, with the notable exception of the Exxon Valdez oil spill monitoring, there apparently does not exist any report on the state of the Alaska coast with respect to marine environmental contamination (such as exists for other states and regions). Any effort at synthesis would be a "first."

With this in mind, the Panel decided to move ahead. As will be evident, below, this may be the first time that specific statements can be made about the status and trends of a host of contaminants in Alaska marine waters.

Background And Approach

Past and Recent Environmental Chemistry Monitoring Programs

Unfortunately, no region-wide monitoring programs have yet been established along the Alaskan coast to adequately document contaminant trends in Alaskan marine coastal areas. However, there are data from a few sources and localities that might provide some clues. These include the NOAA National Status and Trends Program and the Prince

William Sound Regional Citizens Advisory Council (RCAC) Long Term Monitoring Program. A relevant data source is the NOAA National Status and Trends (NS&T) Program. From 1984 to 1990 the NOAA NS&T Program analyzed contaminants in sediments and bottom fish at several Alaska sites as part of a nation-wide "Benthic Surveillance" program conducted by the NOAA Fisheries Montlake Laboratory in Seattle. In 1986, the NOAA NS&T Program began measuring contaminants in intertidal mussels, and adjacent sediments, at several Alaska sites as part of a new National "Mussel Watch" (MW) Program (O'Connor, 1998). That sampling has continued through 2001 at five sites (Mountain Point near Ketchikan, Nahku Bay adjacent to Skagway, Mineral Creek Flats east of Valdez, Siwash Bay at Unakwik Inlet in northern Prince William Sound, and Homer Spit in Cook Inlet). Sampling at the Valdez and Unakwik sites began in 1986 whereas sampling at the other three did not begin until 1993.

The data from these programs are relevant because they include most of the contaminants also analyzed in the 2000 and 2001 cruise ship wastewater monitoring conducted under the Alaska Cruise Ship Initiative. The chemical list includes PCBs, organochlorine pesticides (such as DDTs), polycyclic aromatic hydrocarbons (PAHs) and a suite of 14 trace metals (such as lead, Pb, copper, Cu, and mercury, Hg).

The data from these programs are also relevant because the sites are located along routes of high vessel activity. For example, Mountain Point is located on a channel at the entrance to Ketchikan; the Nahku Bay site is less than one mile from the Skagway docks; Mineral Creek Flats is inshore of the vessel traffic route approaching Valdez; the Siwash Bay, Unaqwik Inlet site is along the route between Valdez and Whittier, and; Homer Spit is at the entrance to a busy vessel port. If vessels are discharging sufficient amounts of wastewaters near these areas, or if they have done so in the past, their contributions to contaminants could be measurable.

Why Mussels?

Mussels are filter feeding bivalve (two-shelled) mollusks that live in sometimes-large clusters in the inter-tidal zone along the entire North American coastline. They attach themselves to rocks and other surfaces (floats, pilings) where they filter large quantities of water, straining out tiny marine algae and other particles. Mussels accumulate contaminants (metals, pesticides, hydrocarbons) and other trace substances in their soft tissues, from very low (often undetectable) concentrations in the water. They can retain accumulated contaminants for periods of several weeks to several months (depending on the contaminant, water temperature, and season). As a result, mussels are extremely cost-effective biomonitors of contaminants in the adjacent water and have been used by environmental chemists for four decades to track patterns and trends of chemical contamination in coastal areas. The one- to three-inch long blue mussel, *Mytilus trosselus*, is the most common intertidal mussel in sheltered areas along the coast from the Aleutians to northern California, where it is replaced by the very similar European mussel, *Mytilus edulis* and, on exposed coastlines, by the large California mussel, (*Mytilus californianus*).

Mussels from Baja California to British Columbia were first used as biomonitors during the 1960's to track the rise and fall of radionuclide contamination originating from atomic testing in the Pacific and discharges from the Columbia River (Hanford) in Washington. Since then mussels, and oysters, have been employed in numerous national, regional and local surveys to monitor trends in chemical pollution. In Alaska, beginning in the early 1990's, the Prince William Sound Regional Citizens Advisory Committee (PWS RCAC) has employed a "mussel watch" program to track contaminant trends in that area. Since 1986, the NOAA National Status and Trends (NS&T) Program has used mussels (and, on the east coast, oysters) to track contaminant trends at the national and regional scale. The NOAA NS&T Mussel Watch Program has five mussel watch sites in Alaska as part of its 250 station program.

The 2000-2001 Mussel Watch program generated data on 106 individual chemical analytes including 18 PCB congeners, 6 DDT isomers, 3 dieldrin-related pesticides (dieldrin, aldrin and endrin), 7 chlordane-related compounds, 4 hexachlorohexane compounds (HCHs, including lindane), pentachloroanisole (a pentachlorophenol product), 4 chlorinated benzenes, mirex, chlorpyrifos, three butyltin compounds and 14 trace elements (such as cadmium and mercury). Many of these chemicals have also been measured in passenger vessel wastewater.

Constraints and Limitations of the NOAA NS&T Program Sampling

There are clear constraints on using and interpreting mussel and surface sediment contaminant data from these sites. There are many sources other than passenger vessels, such as surface water runoff and land-based point sources. If a "hit" (high concentration) of a chemical is discovered, the source will remain uncertain pending further investigation.

There is a second constraint to using these data. Samples collected to date were taken in late-winter/early-spring, just before the tourist season begins. Mussels retain contaminants for several weeks to months and are a good indicator of recent pollution activity but not necessarily pollution from sources occurring a year earlier than the collection. Thus the data currently available for Alaska probably are most useful in documenting pre-season or "background" contamination. Surface sediments will retain contaminants much longer, but are also subject to burial by fresh sediment, and considerable mixing, so that their contaminant concentrations may not reflect the most recent inputs.

Mussel Watch Results

In Appendix 9, Tables D-1 to D-3 summarize contaminant concentrations in mussels from the five Alaska sites sampled in March through April 2001. Data from each site are presented along with a statistical summary. In addition, we present a statistical summary of 2000 and 2001 contaminant concentration data from 58 sites along the remainder of the US West Coast, from Imperial Beach, California to Point Roberts, WA, near the US-Canada boundary. This summary allows comparison of the Alaska sites with those elsewhere on the same coast, providing perspective. In addition, we began, but did not

complete, an analysis of long-term trends at the Alaska sites and at selected remote West Coast sites. We also began, but did not complete, a comparison of 2001 Alaska mussel contaminant concentrations with relevant subsistence seafood consumption guidelines.

A summary of our findings for each chemical group is presented in the discussion, below.

Polycyclic Aromatic Hydrocarbons (PAHs)

(Refer to Appendix 9 Tables-D-1a and D-1b)

Polycyclic aromatic hydrocarbons include a wide variety of "ring" or "benzene" compounds that are present in crude oil, fuels, and products of combustion, including internal combustion engine emissions, cigarette and wood smoke. PAH compounds range from two-ring volatile easily evaporated) chemicals, such as naphthalenes, to large five- and six-ring non-volatile compounds such as benzo-(a)-pyrene, a potent carcinogen. A total of 44 PAH compounds have been monitored in the National Mussel Watch Program, a number sufficient to produce "fingerprints" that may help distinguish sources oil, fuels, combustion, etc).

Status. The 2001 average total PAH (T PAH) concentration in mussels from the five Alaska sites was 86.6 ppb dry weight (dw) ranging 3-fold from 52.5 ppb dw in the mussels from Unakwik Inlet to 144 ppb dw in the samples from the Homer Spit site. By contrast, the average T PAH concentration in mussels for the remainder of the West Coast was nearly 10 times higher, 1982 ppb dw with a range of 34.8 to 46,700 ppb dw (at a site in Elliot Bay near Seattle).

Concentrations of individual PAH compounds are shown in Table D-1a. Naphthalene was the dominant PAH at all five sites, ranging from 8.6 to 14.1 ppb dw. This was followed by phenanthrene with an average concentration of 10.7 ppb dw. By contrast, the dominant PAHs in mussels from the remainder of the US West Coast in Table D-1b were fluoranthene (average 326 ppm dw) and pyrene (193 ppm dw).

The large number of PAH's analyzed in these mussels can be used to help us determine whether the sources are primarily from spills or from combustion products. One tool is the Fossil Fuel Pollution Index (FFPI), which is the ratio of the sum of all PAHs directly derived from oil or coal divided by the total of all PAHs. A high ratio (well above 0.5) indicates oil or fuel may be a dominant factor whereas a low ratio (well below 0.5) would suggest dominance by combustion sources. The FFPI for North Slope crude oil is 0.95. The average FFPI for the PAHs in mussels sampled from the Alaska sites in 1997 was 0.56 ranging from 0.45 at the site near Skagway (NBES) to 0.68 at the Homer Spit site. By contrast, the average FFPI for PAHs in mussels from the remainder of the West Coast was 0.45, ranging from 0.16 to 0.88. This means that Alaska PAH compounds tended to reflect oil or fuel as a source whereas elsewhere along the US West Coast more of the PAH pattern was driven by combustion sources.

Trends. Analytic uncertainties preclude developing long-term trends for PAHs using data prior to 1990. Concentrations in mussels from the Alaska sites varied in the range of about 50 to 200 ppb dw TPAH (18) with a trend of variable but higher concentrations, at

the two long-term sites, to about 1995-97, and decreasing at all five sites thereafter. By comparison, TPAH concentrations in mussels along the outer coast of the Pacific Northwest (PNW) (12 sites) have been comparable, in the range of 20 to 400 ppb dw, but with no clear trend other than low concentrations in the mid-90's. By 2001, TPAH 18 concentrations at the Alaska sites were in the range of 20 to 80 ppb dw whereas those along the PNW outer coast were in the range of 20 to 300 ppb dw.

Polychlorinated Biphenyls (PCBs)

(Refer to Tables D-2a and D-2b)

Status. The 2001 average (mean) total PCB concentration in mussels from the five Alaska sites was 13.1 ppb dw ranging from 7.81 ppb dw at Unakwik Inlet to 24.3 ppb dw at the site near Skagway. By contrast, the 2000-01 average for the U.S. West Coast (58 samples) was nearly twenty times higher, or 149 ppb dw with a range of 7.5 ppb dw at the Humbolt Bay jetty to 1430 ppb dw at San Diego's Harbor Island.

Comparison to Seafood Consumption Guidelines. On a wet weight (ww) basis, the basis for evaluating seafood consumption risk, the Alaska value is about 1.6 ppb ww (range 1.3 to 4.9 ppb ww). EPA, although very conservative in its risk assessment modeling and recommendations, has not established a current screening value for subsistence fishers who utilize mussels as a significant part of their diet. However, under EPA's most recent guidance for assessing chemical contaminant data for use in fish tissue advisories (USEPA, 2000), a screening level of approximately 10 ug/kg (ppb, wet weight) total PCBs in fish tissue is calculated as the upper level value below which non-carcinogenic health endpoints due to PCBs would be unlikely in subsistence fishers. Using theoretical carcinogenic health endpoints as an even more conservative risk assessment endpoint—a screening value for "avoiding" theoretical excess PCB cancer risk of 10^-5 (or one chance of excess cancer in one hundred thousand)—is calculated by EPA using a fish tissue level of about 2.4 ug/kg, wet weight total PCBs. These values are based on an individual who consumes about 19 meals per month (calculated at about 142.4 g/day, for a 70 kg individual over a 70 year lifetime. Thus (in contrast to PCB levels noted for mussels along the coast of the Lower 48) the average PCB concentrations in mussels from these five Alaska sites are consistently below even EPA's most conservative and recent modeled subsistence risk estimates for PCBs in fish tissue.

Trends . Over the period 1986 to 2001, T PCB's concentrations in mussels from the Alaska sites varied from 1 to nearly 100 ppb dw and with a very distinctive longterm pattern or cycle. Concentrations at the two very longterm (14 year) sites, Valdez and Unakwik Inlet, were high in 1986 decreasing by a factor of 10 (to about 10 ppb dw) by the early 1990's, then increasing to a second peak (30 to 40 ppb dw) in 1999 and decreasing again to 10 to 20 ppb dw in 2001. Sampling did not begin at sites at Ketchikan, Skagway and Homer Spit until 1995, but these nonetheless followed the long-term trend at that time: increasing until 1999 and then decreasing.

Comparable data from 11 sites along the outer coast of the Pacific Northwest (Washington to California) indicate that Total PCB's in mussels there were higher (range

2 to about 300 ppb dw) but also experienced the same long-term temporal pattern (decreasing in the 1980-'s, increasing in the 1990's and decreasing again by 2000-2001). The similarities of temporal patterns between these two regions suggest that both areas experienced the same systematic and/or large-scale pattern, with absolute concentrations at individual varying as a result of local conditions.

DDTs

Status. The 2001 average (mean) total DDT concentration (sum of 6 isomers) in mussels from the five Alaska sites was 1.52 ppb dw ranging from 0.89 ppb dw at Unakwik to 3.3 ppb dw at Skagway. By contrast, the 2000-01 average for the remaining U.S. West Coast (58 sites) was nearly 60 times higher, or 64.9 ppb dw with a range of 2.01 at Fogarty Creek near Yaquina Head, Oregon, to 492 ppb dw at Emeryville near Berkeley, CA.

Comparison to Seafood Consumption Guidelines. On a wet weight basis (the basis for evaluating seafood consumption risk), the Alaska average DDT concentration is about 0.3 ppb ww (range 0.18 to 0.66 ppb ww). As in the case of PCBs, EPA has not developed a screening level for tissue concentrations of total DDT specifically for mussels consumed by subsistence users. However, the current EPA guidance for fish tissue advisories (USEPA, 2000) recommends an upper screening level in edible fish tissue of 245 ppb wet wt. for non-carcinogenic effects, and 14 ppb ww for carcinogenic effects (10^-5 risk level). Thus, the mussels from these five Alaska sites are well below EPA's most recent and highly conservative modeled screening values for assessing theoretical excess health risk due to DDT concentrations in fish consumed by subsistence populations.

Trends. Concentrations of DDT in marine life along the U.S. West Coast have been declining steadily since the pesticide was banned in the early 1980's. An analysis of trends for Alaska is underway.

Chlordanes

Status. The 2001 average (mean) total chlordanes concentration (sum of 7 compounds) in mussels from the five Alaska sites was 1.39 ppb dw ranging from 0.89 ppb dw at Unakwik to 3.0 ppb dw at the site near Skagway. By contrast, the 2000-01 average for the remaining U.S. West Coast (58 sites) was nearly 20 times higher, or 15.9 ppb dw with a range of 1.5 dw at a site in Hood Canal, WA, to 149 ppb dw in Elkhorn Slough, Monterey Bay, CA.

No Alaska mussels contained all 7 compounds. The chlordane compounds measured at highest concentration (i.e., dominating the chlordane mix) at all five sites were heptachlor epoxide, alpha chlordane, and trans-nonachlor. Heptachlor was not found at any site. Oxychlordane was not detected in mussels at two sites: Valdez and Unakwik.

Comparison to Seafood Consumption Guidelines. On a wet weight basis (the basis for evaluating seafood consumption risk), the Alaska total chlordane mean is about 0.3 ppb ww (range 0.18 to 0.6 ppb ww). EPA's current upper level target screening

concentrations (ref) for total chlordane in fish tissue consumed by subsistence fishers are nearly identical for those listed previously for total DDT. For chlordane, the levels for non-cancer endpoints, as well as for theoretical carcinogenic endpoints (10^-5 risk level) are 245 ppb ww. and 14 ppb ww respectively. Thus, as is the case for total DDT residues, the mussels from these five Alaska sites are well below total chlordane fish tissue concentrations which would be likely to pose a likelihood of theoretical health risk concern to subsistence fishers.

Trends. Chlordane was banned for use in the US and Canada in 1977 although remaining stockpiles could be used under specific circumstances (Shigenaka, 1992). Concentrations in mussels at many sites along the US West Coast were declining in the 1980's (Shigenaka, 1992). An analysis of trends for Alaska is needed to confirm concentrations have been decreasing here.

Dieldrin and Related Pesticides

Three compounds make up the dieldrin-related group. The most abundant is dieldrin, which is also the common environmental degradation product of aldrin.

The 2001 average (mean) dieldrin concentration in mussels from the five Alaska sites was 0.44 ppb dw, ranging from 0.23 ppb dw at Valdez to 0.85 ppb dw at the site near Skagway. By contrast, the 2000-01 average for the remaining U.S. Pacific Coast (58 sites) was nearly 20 times higher, or 7.32 ppb dw with a range of 0.42 at a Coos Bay, OR, site to 184 ppb dw at Emeryville near Berkeley in San Francisco Bay. Aldrin was not detected at any Alaska site whereas its mean concentration along the remaining West Coast was 0.03 ppb dw (range 0 to 1.66 ppb dw). Endrin was detected at one of the five Alaska sites, near Skagway (0.12 ppb dw). Its mean concentration along the remaining Pacific Coast was 0.54 ppb dw ranging from 0 to 9 ppb dw.

Dieldrin pesticides may still have limited use in the US, but continuing use elsewhere. An analysis of trends for Alaska is needed to confirm concentrations have been decreasing here.

HCH (Hexachlorohexane) Compounds

The pesticide lindane (gamma HCH) was commonly used during the mid 20th century; it and related HCH compounds are banned in US, but still in wide use around the globe.

The 2001 average (mean) total HCH concentration (sum of 4 compounds) in mussels from the five Alaska sites was 2.03 ppb dw, ranging from 1.16 ppb dw at Valdez to 2.47 ppb dw at Homer Spit. The 2000-01 average for the remaining U.S. Pacific Coast (58 sites) was nearly the same or 2.54 ppb dw, but with a range of 0.29 to 8.67 ppb dw. Thus HCHs are one group of compounds for which the Alaska sites have levels of contamination similar to those along the rest of the West Coast.

Lindane (gamma HCH) was present in mussels at all five Alaska sites but was not the major HCH compound. Delta HCH was not detected at any of the sites. Alpha HCH

dominated total HCH concentrations in samples from all five sites. Beta HCH was the second most abundant HCH at four sites.

Concentrations of HCH compounds in Alaska, mean 0.38 ppb, are similar to those in the lower West Coast sites, mean 0.42 ppb. This is not surprising and is consistent with our current knowledge that these compounds condense in northern latitudes from global atmospheric sources (e.g., Simonich and Hites, 2001). An analysis of trends for Alaska is needed to confirm the suspicion that concentrations are being maintained and perhaps increasing here.

Chlorpyrifos

Chlorpyrifos was detected in mussels from four of the Alaskan sites in 2001. The mean concentration was 0.4 ppb dw ranging from 0 at Ketchikan to 0.73 ppb dw at Skagway. The 2000-01 average for the remaining U.S. West Coast (58 sites) was 0.39 ppb dw ranging from 0 at many sites to 3.78 ppb at the Samoa Bridge near Eureka, CA.

Mirex

Mirex was not detected at any Alaska site in 2001. The 2000-01 average for the remaining U.S. West Coast (58 sites) was 0.07 ppb dw with a range of 0 at many sites to a maximum of 0.77 ppb dw at one site.

Chlorinated Benzenes

Four chlorinated benzenes were measured in mussels from all five Alaska sites. The most abundant was the pesticide and fumigant, hexachlorobenzene, HCB.

The average concentration of HCB in the 2001 Alaska mussels was 0.60 ppb dw ranging only two-fold, from 0.48 ppb dw at Homer Spit to 0.97 ppb dw at the site near Skagway. These concentrations are similar to those for the entire Pacific Coast with a mean of 0.64 ppb dw and ranging from 0 at Imperial Beach near the US-Mexico border, to 10.9 ppb dw at Samoa near Eureka, CA.

Tetra 1,2,3,4 chlorobenzene was detected in mussels at four Alaska sites in 2001. The average was 0.09 ppb dw with a range of 0 at Skagway and Valdez to 0.3 at Unakwik Inlet. Concentrations in mussels from the remaining West Coast (58 sites) averaged 0.04 and ranged from 0 at most sites to 0.52 ppb dw at Point St. George on the northern California coast.

Tetra 1,2,4.5 chlorobenzene was not detected in any Alaska mussels in 2001. Concentrations in mussels from the remaining West Coast (58 sites) ranged from 0 at most sites to 3.21 ppb dw at Cape Flattery on the Washington coast.

The average concentration of pentachlorobenzene in Alaska mussels was 0.08 ppb dw ranging from 0 at Valdez to 0.12 ppb dw at the Skagway site.

Chlorophenols

Pentachloro anisole is a derivative of pentachlorophenol, a formerly-popular wood preservative. Pentachloroanisole was detected in low concentrations in mussels at all five Alaska sites sampled in 2001, with a average of 0.24 ppb dw and ranging from 0.20 at Unakwik to 0.29 ppb dw at Homer Spit. The average pentachloroanisole concentration in mussels from the remainder of the US West Coast in 2000-01 averaged 1.34 ppb dw, 6 times higher than the Alaskan, with a range of 0.30 ppb dw at Bird Rock, Catalina Island, CA to 4.13 ppb dw at Point St. George in northern California.

Butyltins (Anti-Fouling)

Tributyl tin (TBT) is an organic tin compound widely used in vessel antifouling paints during the 1970's and early 1980's. Its use on vessels smaller than 75 meters was banned in the US during the mid 1980's, but its use continued on hulls of larger ships.

TBT was detected and quantified in mussels from all five Alaska sites sampled in 2001. The average concentration was 4.97 ppb dw ranging from 2.93 ppb dw at Unakwik Inlet to 7.43 ppb dw at the site near Valdez. The site near Skagway had the second highest concentration, 7.10 ppb dw. By contrast the average TBT concentration in mussels from the remainder of the West Coast in 2000-2001 was eight times higher than in Alaska, with an average of 24.8 ppb dw ranging from 0 to 189 ppb dw in mussels from the San Pedro Fishing Pier, California.

Two TBT "sister" compounds, monobutyl tin (MBT) and dibutyl tin (DBT) were also detected at the Skagway site (3.72 and 8.96, respectively) and the Valdez site (2.27 and 5.57 ppb dw, respectively. Dibutyltin was also detected (2.14 ppb dw) at the Homer Spit site. Neither compound was detected at the Ketchikan nor Unakwik Inlet sites. The average concentrations of these compounds in mussels from the remainder of the West Coast were 1.95 and 9.89 ppb dw, respectively, with the highest concentrations at 39 and 80 ppb dw, respectively. A fourth butyltin, tetrabutyltin, was not detected at any site in Alaska or along the remainder of the US West Coast.

Lipid Content

Variations in lipid (fat) content of marine animals can affect interpretation and comparison of organic chemical concentrations. Lipid concentrations in the 2000 Alaska mussels averaged 3.85% dry weight (0.54% on a wet basis) with a range of 2.62% at Valdez to 4.76% at the site near Ketchikan. These concentrations were somewhat lower than those for the entire Pacific Coast: the average was 5.05% with a range of 2.8 to 13.2 %.

Trace Elements

(Refer to Tables D-3a and D-3b)

Human health standards for the consumption of seafood are included for several elements. Please note that standards do not exist for all elements.

Silver (Ag)

Silver concentrations in mussels vary considerably and, in the past, high concentrations have been interpreted as indicators of sewage pollution (Martin et al., 1988). The high concentrations once indicative of municipal wastewater no longer exist. Sources of silver from cruise ships could include photo-lab wastes and wastewater from silverware; the same is true for sources from adjacent towns and cities.

The average concentration of silver in mussels collected in 2001 in Alaska was 0.75 ppb dw, ranging from 0.15 at Homer Spit to 1.70 at the Unakwik Inlet site (Table X- 2). By contrast, silver concentrations in mussels from the remainder of the West Coast collection averaged 1.01 ppm dw ranging from 0.03 at Port Townsend, WA, to 6.48 ppm dw at the Oceanside Beach Jetty in San Diego County, CA.

Aluminum (Al)

Aluminum is the most common metal on the earth, but has no known biological function. Its presence in mollusks may indicate the amount of sediment they have filtered.

The average concentration of aluminum in the 2001 Alaska mussel samples was 644 ppm with a range of 62 to 1149 ppm dw. This is comparable to the mean concentration of 506, and range of 29 to 1668 ppm dw in mussels from the remainder of the West Coast (Table 3).

Arsenic (As)

Arsenic, a potent poison when bioavailable in sufficient concentrations, is a natural trace element in the ocean, but can be increased locally by anthropogenic sources such as mining operations. The average concentration of arsenic in the 2001 Alaska samples was 13.6 ppm dw ranging from a low of 12 ppm dw in the Skagway mussels to 15 ppm dw in the Unakwik samples. These concentrations are slightly higher than the average (11.6 ppm dw) for the remaining West Coast mussels, where the range was higher (5.9 to 30.8 ppm dw).

Over the period from 1986 to 2001, arsenic concentrations in mussels from the two Alaska sites (Homer Spit and Unakwik Inlet) experienced concentrations in the same range (8 to 15 ppm dw) as in mussels from the three Pacific Northwest sites (Cape Flattery and Grays Harbor Jetty, WA, and Hobson Point, Tillamook Bay, OR). No long-term trend was obvious in either region, but arsenic concentrations at the Alaska sites appeared to decrease from 12 to 15 ppm dw in the 1980's to 10 ppm dw in the early 1990's and then increase again thereafter, whereas concentrations experienced more inter-annual variation at the Pacific Northwest sites.

There is a possibility that arsenic, like cadmium (see below) is higher in mussels from open coastal promontories which can experience episodes of upwelling of deep ocean water containing naturally-enriched concentrations of several trace elements.

Cadmium (Cd)

Cadmium, common in batteries and other metallurgical materials, is also toxic in sufficient concentrations and, like arsenic, is also a natural trace element in the oceans. The average concentration of cadmium in the 2001 Alaska samples was 4.33 ppm dw ranging from a low of 1.95 ppm dw in the Homer Spit mussels to 6.28 ppm dw in the samples from the site near Skagway. These concentrations are nearly identical to the average (4.24 ppm dw) for the entire Pacific Coast collection, but the range there was wider (0.43 to 15.6 ppm dw).

Over the period 1984 to 2001, cadmium concentrations ranged from about 2 to 5 ppm dw in mussels from the two Alaska sites but from 4 to nearly 12 ppm dw in mussels from one of the more remote Pacific Northwest sites, Cape Flattery. Despite the high inter-annual variability at the Pacific Northwest sites, there was no long-term trend in either region.

As mentioned above, it is now well known that high concentrations of cadmium can occur in mussels and other shellfish collected near upwelling areas (Stephenson et al., 1979a).

Chromium (Cr)

Chromium is a common industrial metal with high toxicity in its most oxidized form, chromate. However, the dominant form in sewage is the non-toxic trivalent form. It is also a natural trace element in the ocean and especially in serpentine (?) soils, which occur in scattered locations along the Pacific Coast. The average concentration of chromium in the 2001 Alaska samples was 2.08 ppm dw ranging from a low of 0.71 ppm dw in the Skagway mussels to 6.01 ppm dw in the samples from the Unakwik Inlet site. These concentrations are slightly lower than the average (3.1 ppm dw) for the remainder of the West Coast mussels, but the range there was higher (1.07 to 11.8 ppm dw).

Copper (Cu)

Copper is a potentially toxic (to aquatic organisms) trace element with many uses. It is a significant component of Alaskan geology and a natural trace element in the ocean. The average concentration of copper in the 2001 Alaska samples was 8.4 ppm dw, ranging from 7.17 ppm dw in the Ketchikan mussels to 10.8 ppm dw in the samples from Unakwik Inlet. The Alaska concentrations are slightly lower than the average (9.1 ppm dw) for the remainder of the West.

Mercury (Hg)

Mercury is a toxic trace element with well-known uses in medicine, electronics and other activities. It too is a natural trace element in the ocean, and, with the possible exception of cadmium in certain situations, is the only metal (in an organic form) known to undergo

biomagnification through marine food chains. The average concentration of mercury in the 2001 Alaska mussel samples was 0.110 ppm (110 ppb) dw, ranging three-fold, from 0.083 ppm (83 ppb) dw in the Valdez mussels to 0.154 ppm (154 ppb) dw in the samples from Unakwik Inlet. These concentrations are slightly lower than the average (0.137 ppm or 137 ppb dw) for the remainder of the West Coast.

The traditional seafood safety limit has been 0.5 or 1.0 ppm, but on a *wet weight* basis (USEPA 2000). The values reported above are dry weight. Mussel tissue averages about 80% water. Therefore on a wet basis (dry concentration divided by about 5), the 2001 Alaska mussel mercury concentration averaged 0.022 ppm with a range of 0.016 to 0.030 ppm ww, all well below the 0.5 ppm ww criteria USEPA 2000).

Over the period (1984 to 2001) mercury concentrations in mussels from the Alaska sites varied 6-fold from about 0.025 to 0.15 ppm dw with a slight increase over the long term monitoring period.

Manganese (Mn)

Manganese is an important trace element with moderate toxicity, yet also occurs naturally in the ocean. The average concentration of manganese in the 2001 Alaska mussel samples was 20.9 ppm dw, ranging three-fold, from 9.37 ppm dw in the mussels from Ketchikan to 28.1 ppm dw in the samples from the site near Valdez. These concentrations are slightly lower than the average of 23.9 ppm dw for the remaining West Coast samples, but the West Coast range was higher, 4.4 to 146 ppm dw.

These values are much lower than the human health criteria of 100 ppm for the consumption of seafood (USEPA 1976 and USEPA 1999).

Nickel (Ni)

Nickel is a common trace element with moderate toxicity, yet also occurs naturally in the ocean. The average concentration of nickel in the 2001 Alaska mussel samples was 3.93 ppm dw, ranging three-fold from 1.51 ppm dw in the mussels from Ketchikan to 7.03 ppm dw in the samples from the site near Valdez. These concentrations are slightly higher than the average 2.69 ppm dw for the remainder of the West Coast samples, but the West Coast range was higher 0.25 to 8.7 ppm dw.

These values are much lower than the human health criteria of 4,600 ppm for the consumption of seafood (USEPA 1999).

Lead (Pb)

Lead, once used in American gasoline, is not considered to be a natural trace element in the oceans. The average concentration of lead in the 2001 Alaska mussel samples was 1.04 ppm dw, ranging over six-fold from low of .37 ppm dw in the mussels from Ketchikan to 1.78 ppm dw in the samples from the site near Skagway. This mean concentration is substantially lower than the mean of 1.43 ppm dw for the entire Pacific Coast collection, but the Pacific Coast range was higher (0.14 to 7.2 ppm dw).

The slightly higher value at Skagway is not unexpected since the mussel watch site is close to the old lead processing facility west of the city.

Selenium (Se)

The average concentration of selenium in the 2001 Alaska mussel samples was 5.3 ppm dw ranging two-fold, from low of 3.73 ppm dw in the mussels from Valdez to 8.1 ppm dw in the samples from the site at Unakwik Inlet. These concentrations are slightly higher than the average 4.3 ppm dw for the remainder of the West Coast, but the West Coast range was slightly higher 2.13 to 10.6 ppm dw. Both the Alaska and West Coast values are much lower than the 11,000 ppm standard for the human consumption of seafood (USEPA 1999).

Tin (Sn)

The NOAA NS&T Program measures total tin as well as the organic-bound butyltin compounds described above. Aside from the synthetic butyltin formulations, tin is a commonly used and toxic trace element, with no known biological function. The average concentration of tin (total tin) in the 2001 Alaska mussel samples was 0.279 ppm dw ranging widely from low of 0.003 ppm dw in the mussels from Homer Spit to 0.993 ppm dw in the samples from the site near Valdez. These concentrations are identical to the average 0.274 ppm dw for the remaining West Coast, but the West Coast range was slightly higher, 0 to 1.66 ppm dw.

Zinc (Zn)

Zinc is a common trace element in the ocean, a required trace element for life, and common in wastewaters. The average concentration of zinc in the 2001 Alaska mussel samples was 82 ppm dw ranging two-fold, from low of 48 ppm dw in the mussels from Valdez, to 111 ppm dw in the samples from the sites at Unakwik Inlet. These concentrations are lower than the average 168 ppm dw for the remaining West Coast sites, and the West Coast range was higher, 70 to 309 ppm dw). Both the West Coast and Alaska values were much lower than the standards for human consumption of seafood, 69,000 ppm (USEPA 1999).

Discussion and Implications

This brief analysis of data from five Alaska sites, when compared with a larger body of comparable data for the entire US Pacific Coast (58 sites), is sufficient to demonstrate that shorelines of Southeastern Alaska, Prince William Sound, and Cook Inlet have experienced relatively low levels of contamination by petroleum hydrocarbons, most chlorinated hydrocarbons, and butyltin-based anti-fouling compounds. With several notable exceptions, concentrations of PAHs and organochlorine compounds in Alaskan muscles have been several to 20 times lower than muscles in the rest of the US Pacific Coast. The notable exception is for several HCH (lindane-related) compounds. The analysis also indicates that the Alaska mussels contain all common trace elements

characteristic of marine ecosystems, but at concentrations that do not appear to be unusual, abnormal, or present a threat to human health.

Status

Traces (low part per billion concentrations) of various organochlorine compounds (PCB's, pesticides) and butyltin (from antifouling paint) occurred in mussels from all five Alaska sites sampled during the spring of 2001. For most organic chemicals, concentrations in Alaska mussels were much lower than in mussels elsewhere along the U.S. Pacific Coast (California, Oregon and Washington). Average concentrations of PAHs and PCBs in the Alaska mussels were ten and twenty times lower, respectively than the averages in mussels along the rest of the West Coast; however, other data associated with oil spill monitoring indicated that PAHs in mussels from certain Alaska marinas and boat harbors are extremely high. Several organochlorines, namely lindane-related compounds (HCHs) and the fumigant hexachlorobenzene (HCB) in mussels from Alaska were comparable to or higher than in those from further south along the U.S. west coast: this is probably due to the precipitation of these compounds from global atmospheric sources. For trace metals, concentrations in Alaska mussels have been typical of expected "background" concentrations: however, the trace metal lead (Pb) has been elevated in mussels from a site at Skagway.

Trends

Time and resources did not permit a thorough analysis of long-term trends of contamination in mussels from Alaska. However, we prepared graphs for a few contaminants (PCBs and three metals). Over the period 1986 to 2001 there was a long-term trend of declining and then increasing total PCB concentrations at the two long-term Alaska sites (Homer Spit and Unaqwik Inlet). The rise, during the 1990's, was also matched by a rise at the three shorter-term monitoring sites (Valdez, Skagway and Ketchikan). However, the fall and rise during the past decade was not unique to the Alaska sites; it was observed at many sites in Washington, Oregon and California, suggesting the possibility of a long-term rise in global atmospheric inputs to the North American Coast.

Concentrations of PAHs at the two long-term sites increased until about 1995-97. Since then, concentrations at all five sites have been decreasing. By comparison, Total PAH concentrations in mussels along the outer coast of the Pacific Northwest have been comparable but with no clear trend other than low concentrations in the mid 1990's. By 2001, Total PAH 18 concentrations at the Alaska sites were in the range of 20 to 80 ppb dw, whereas those along the Pacific Northwest outer coast were in the range of 20 to 300 ppb.

None of three trace metals analyzed for long-term trends (arsenic, cadmium and mercury) displayed increases in concentration since 1986. Trends have not yet been examined for other metals.

Biomagnification

While concentrations of these contaminants are generally lower in Alaska mussels than in those from elsewhere in the US, there may be concern that concentrations are elevated at higher levels in the food web such as in large fish, mammals, and birds. This process is called biomagnification. Studies have not been conducted in Alaska to determine if these substances have been undergoing biomagnification. However, detailed food-web studies have been done in other marine coastal areas and they clearly support the idea that biomagnification is an exception in marine food webs, not the rule. Mercury and DDT clearly undergo biomagnification, PCB's to some extent and cadmium in special situations (walrus). However, all PAHs and all other metals actually experience biodimunition: concentrations are lower in animals higher in the food web than mussels.

Sources

Given this information, what kinds of statements can be made about sources, specifically passenger vessels? The primary routes of cruise ships include the Inside Passage of Southeast Alaska, from Ketchikan to Skagway, and Glacier Bay. However, many go on to Valdez, Whittier, Seward, Homer, and Anchorage and beyond. Small passenger vessels, including ferries and tour boats, also connect adjacent communities in Southeast, Prince William Sound, the Kenai and Cook Inlet. Most are seasonal but state ferries operate year round, along with oil tankers, and cargo and container ships and barges. Floatplanes and private boats may be considered small passenger vessels as well.

Selected contaminants - PAHs, PCBs, arsenic, cadmium, and mercury- measured in the Mussel Watch program in Alaska were either declining or remaining unchanged over time during the past decade and during a period, presumably, of increasing passenger vessel activity. This suggests that along-shore vessel activity is not adding to the loads of these chemicals at the sampled locations.

The data presented here are insufficient to distinguish passenger vessels from other sources of contamination, which could include industrial activities, surface water runoff (including deposition from global atmosphere), land-based wastewater discharges, or even wastes deposited from large concentrations of wildlife. The data do suggest that if cruise ships have been contributing to the low contaminant loads, their contribution has been minor compared to the sources of long-term and large-scale variability. In addition, the Panel's literature review, fieldwork, research and modeling reported in this paper (specifically Sections I, V, VI & VIII) tend to confirm this assumption.

The Alaskan mussels showed trends for PCB's that are generally consistent with our current understanding of large-scale geographic patterns and trends. That is, (1) at any point in time, Total PCB's are considerably lower in Alaska than along the US west coast near urban areas and (2) the primary factor causing secular trends or inter-annual variation is large-scale, not local.

The large number of PAH's analyzed in these mussels provided the opportunity to "fingerprint" them with respect to two possible sources: fossil fuel and combustion. As

noted above, the average Fossil Fuel Pollution Index (FFPI) suggests that the PAHs in Alaskan mussels originate more from fuel and oil than from combustion whereas along the rest of the US pacific Coast, especially in areas of heavy PAH contamination, the primary source is combustion. The implication is that, despite proximity to cities such as Ketchikan, Skagway, Valdez, and Homer, the mussels from these four sites are not experiencing substantial pollution from combustion sources. Small spills would be more likely sources.

Although the core NS&T Mussel watch sites do not indicate an increasing trend of coastal contamination, it should be noted that marinas and boat harbors themselves may be important continuing sources of hydrocarbons. Since 1989, PAHs have been frequently monitored in mussels and clams from the Exxon Valdez oil spill area, ranging from Prince William Sound west to the Kenai, Cook Inlet, and the Kodiak Island group (Short et al., 1996; Shigenaka et al. 1997; RCAC, 2001). These data generally show that PAHs declined from extremely high to near-background concentrations by the mid-1990s. However, they also show that mussels from marinas and boat harbors in Alaska are heavily contaminated with petroleum-derived PAHs. For example, one of the highest concentrations of total PAHs ever recorded in U.S. mussels was about 33,000 ppb dw in animals sampled from a dock in Cordova Harbor (Mearns et al., 1999); mussels on a dock in Whittier Harbor in 1997 had a concentration of over 11,000 ppb dw and an FFPI of 0.80, indicating heavy contamination, presumably from small fuel spills.

PCBs in the Alaska mussels may be originating from both local and global sources. The variation of PCB concentrations among the Alaska sits is low and none of the sites appear to be near PCB "hot spots". However, like HCHs, there may be important atmospheric sources of PCBs to Alaska coastal waters.

The barely-detectable presence of chlorpyrifos in Alaskan mussels suggests that local or regional usage of this pesticide may need to be watched.

Silver, a potential indicator of sewage pollution, was not detected in any of the 1997 Alaska mussels, but was detected in muscles from urban coastal waters in California. This may be an indication that human activity in Alaska is not contributing sufficient wastewater to cause silver to rise above detection in filter-feeding mussels.

For several metals, sites most remote from human habitation had higher concentrations than those near urban areas. It is now well known that, as described above, high concentrations of cadmium can occur in mussels and other shellfish collected near upwelling areas (Martin et al., 1976). There is a possibility that arsenic, like cadmium, is higher in mussels from open coastal promontories, which can experience episodes of upwelling of deep ocean water.

Assessment and Monitoring Recommendations

It is hoped that this brief assessment will provide stimulus to continue and enhance environmental contaminant monitoring in coastal Alaska.

What if any additional assessment and monitoring needs to be done to make sure passenger vessels and other sources are not contaminating Alaskan shorelines?

Obviously, this section has stressed the importance of a "mussel watch" type program for evaluating the status and trends of contaminants in Alaskan marine waters. Much remains to be done with the existing data, especially for analyzing trends and sources (using chemical fingerprint techniques). Further, data from past sediment sampling need to be examined.

However, as intense as the NS&T sampling has been, it embodies only five basic stations covering a thousand miles of shoreline, with samples taken just before the tourist season begins. None of the sites are in protected and ecologically sensitive areas such as Glacier Bay, Taku Inlet, Tracey Arm, or College Fjords.

An Alaska Mussel Watch program could be a cost-effective and useful tool for tracking contaminant trends regardless of the concern or sources. An obvious recommendation is to considerably increase the number of contaminant mussel watch sites in coastal Alaska and sample before and after the tourist season.

Based on experience elsewhere, it is unlikely that any of the trace elements have sources significant enough to cause long-term contamination at the scale of large water bodies except immediately adjacent to mining operations. Certainly there can be local sources and gradients that could be reflected in "tight-grid" mussel monitoring, such as for lead at Skagway. Otherwise, trace metals might be lower priorities for monitoring.

Although over a hundred chemicals are being analyzed in the NS&T program, these may not be the contaminants of most concern with respect to tourism and passenger vessel activity. To our knowledge there has been no effort in Alaska to measure or monitor materials such as estrogen mimics, fragrance materials (FM's), or linear alkyl benzosulfonates (detergent chemicals). Section VI, which addresses the impact of wastewater on the sea surface microlayer, includes a discussion other kinds of contaminants to monitor.

Acknowledgements

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References

Martin, M., M.D. Stephenson, D.R. Smith, E.A. Gutierrez-Galindo, and G. Flores Munoz. 1988. The use of silver in mussels as a tracer of domestic wastewater discharge. Marine Pollution Bulletin 19(10):512-520.

Martin, J.H., K.W. Bruland and W. Broenkow. 1976. Cadmium transport in the California Current. In Marine Pollutant Transfer. H.L. Windom and R.A. Duce. Lexington, MA D.C. Heath and Co. pp 159-184.

Mearns, A.J., T.P. O'Connor and G.G. Lauenstein. 1999. Relevance of the National Mussel Watch Program to seafood fisheries management issues during oil spill response. 701-708 In Proceedings, 1999 International Oil Spill Conference, March 8-11, 1999, Seattle, Washington. American Petroleum Institute Publ. 4686B, Washington, D.C.

O'Connor, T.P. 1998. Mussel Watch results from 1986 to 1996. Marine Pollution Bulletin 37(1-2):14-19.

Shigenaka, G. 1990. Chlordane in the marine environment of the United States: review and results from the National Status and Trends Program. NOAA Technical Memorandum NOS ORCA 55, Seattle, WA.

Simonich, S.L. and R.A. Hites. 1995. Global distribution of persistent organochlorine compounds. Science 269:1851-1854.

Simonich, S.L., W.M. Begley, G. Debaere and W.S. Eckhoff. 2000. Trace analysis of fragrance materials in wastewater and treated wastewater. Environmental Science and Technology, 34: 959-965.

USEPA, 2000. Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 1. Fish Sampling and Analysis. 3rd Ed. Table 5-4. Dose-response variables and recommended screening values (SVs) for target analytes—subsistence fishers. p.5-13. EPA-823-B-00-007. Office of Science and Technology. Office of Water. U.S. Environmental Protection Agency, Washington, D.C. November.

USEPA, 1976. Quality Criteria for Water (also called the *Red Book*) EPA-440/9-76-023

USEPA, 1999. National Recommended Water Quality Criteria-Correction, EPA 822-Z-99-001

Data Sets

(see Pacific.All.SumStat.XLS3) (Pacific.FFPI.SUM.97-98.XLS)

Section XI

Recommendations for Monitoring and Research

The Science Panel finds that, while the risk of environmental impacts from current cruise ship and ferry discharge practices are low, research and development on several topics would assure that uncertainties remain small. These areas include:

- Continued Evaluation of Small Passenger Vessels
- Improved Sampling and Additional Audits of Passenger Vessels
- Determining Water Movement and Exchange in Selected Coastal Areas
- Enhanced Environmental Assessment and Monitoring of Alaska Waters

A. Continued Evaluation of Small Passenger Vessels (Section II & IX)

- Refine dilution estimation for small cruise ship underway discharge.
- Develop best management practices for small cruise ships, particularly for stationary discharge.
- Research "small-package" advanced treatment technology to assist these ships in installing the best technology for their space limitation.

B. Additional Sampling and Audits of Passenger Vessels

1. **Improve Shipboard Sampling (Section II)**. The "representativeness" of samples taken on board should be addressed. Currently, grab samples from holding tanks or a small aliquot from the discharge line are taken at a time that will meet the 6-hour “sample-drawn-to-lab” deadline required for fecal coliform analysis. The emphasis should be taken off sampling to meet the fecal coliform holding time and placed on taking samples that are representative of the total volume of wastewater that gets discharged. A sample subset of actual discharge should be taken, perhaps using a Venturi sampler that would bleed off several liters of wastewater during discharge. From this subset, the sample could be taken.

2. **Continue Shipboard Audits (Section VIII)**. **)**. If cruise operators more precisely document what comes on board and make that information available, regulators and researchers can determine what could be discharged during a spill or from regular use. More efficient monitoring programs can be established with this information.

C. Measure Water Movement and Exchange in Selected Coastal Areas (Section VII)

Identify Alaska waters of low net outflow. Areas where long residence time or minimal neap tidal exchange[40] occurs are areas where pollutants from wastewater discharges may be a problem. Tidal exchange information could be used to prioritize areas for further study to determine whether or not wastewater discharge is a problem (e.g. sensitive areas)

D. Enhanced Environmental Assessment and Monitoring:

Confirm the predictions of no significant ecological effects based on modeling (Section I), dye measurements (Section I), bioassays (Appendix 8), and limited existing monitoring (Section X) by additional ambient monitoring of Alaska waters.

1. **Bacteria Monitoring (Section III)**. Because the public has raised concerns about bacteria the issue of bacteria contamination itself needs to be investigated and characterized in order to educate the public, and to help guide management decisions in the future. Bacteria sampling should be conducted along shores near populated areas, including boat harbors, in order to characterize water quality. It will identify areas violating standards because of natural land-based sources or other human activities, which then may need to be addressed. Large cruise ships are not likely to be a contributor to these areas because they discharge offshore. Small cruise ships will add to ambient bacteria, but their contribution could be minimal compared to other sources.

2. **Measure Sediment Contaminants for Long-term Trends (Section V)**. Conduct specific measurements of chemicals in surface and subsurface sediments collected at and away from cruise ship tracks. ADEC should obtain several sediment cores and have them analyzed for metals and perhaps some other contaminants, along with lead (Pb-210) dating, so that it is possible to describe background sediment levels and to see what trends might be evident. Mercury and PCBs should be included, since there are global inputs of these contaminants. This is simply information that ADEC should have every 5 or 10 years. The program should take a few cores for similar analysis from other areas as selected by an advisory panel, and return to original sites in 10 years to see if anything new is evident.

3. **Measure Mussel Contaminants for Seasonal and Inter-annual Trends (Section X).** Increase the number of "mussel watch" sites in coastal Alaska, and adjust sampling to encompass the tourist season, and increase sampling

[40] Neap tides occur just after the first and third quarters of the lunar month. At these times the difference between high and low tides is the smallest. Thus, water movement due to tide flux is the smallest. The Panel recognizes that "minimal neap tidal exchange" must be more precisely defined before it can be used as a criterion for establishing no-discharge zones.

frequency from biennial (NOAA National Status and Trends Program) to annual or semi-annual (beginning/end of tourist season).

4. **Review Existing Programs to Incorporate or Consolidate Project Data Relevant to Continued Research.** The state has data collected from various coastal and marine locations. These databases can be used in conjunction with cruise ship sample data to determine impacts and trends not only related to cruise ships, but also in Alaska coastal waters in general. For example, there has been a considerable amount of data collected in the Cook Inlet and Prince William Sound regions.

5. **Consolidate monitoring cooperatively into a Coastal Monitoring and Assessment Program**. Continue to maintain and use the State SRP system to track environmental monitoring projects and their data. These data are for discrete areas but spatial gaps in the data may be augmented with the additional sediment and mussel watch monitoring as noted above. The State of Alaska has a unique opportunity to develop a coastal monitoring program supported by, and under the leadership of, all stake holders (tourism industries, National Park Service, National Marine Fisheries Service, ADEC, Alaska Department of Fish and Game, Governor's Office, EVOS Trustee Council, Regional Citizen's Advisory Council, state ferries, port authorities, fishery cooperatives, mining). Models for this stakeholder, or otherwise cooperative approach already exist: the Puget Sound Ambient Monitoring Program (PSAMP) (Mearns et al. 2001); the Southern California Coastal Water Research Project (SCCWRP) and the Regional Monitoring Program facilitated by the San Francisco Estuary Institute (SFEI). No such program currently exists in Alaska.

6. **Current-Use and "New" Chemicals (Section VIII).** Consider adding several "new" mass-balance "marker" materials and several additional contaminants to the sampling/analysis watch list. (See Section VIII.) The Panel suggests that several chemicals be added to the list of current chemicals monitored by the State of Alaska. If after one season's monitoring they are not found in the gray water or blackwater, then the monitoring for these chemicals could be discontinued.

    - **Contaminants**. Measure for chlorpyrifos and other new-generation pesticides, cosmetics, fragrances, drugs and fire retardants for environmental impacts and their presence in landside point source discharges which in turn might indicate a need for cruise ship monitoring. In this regard, Alaska should coordinate the research of other states and federal agencies in accessing the significance of the use of these materials and their impact. Selective monitoring in effluents, sediments and mussels would be a natural outcome. Note: This is not targeted at cruise ships. It is a program of adaptive environmental management for the state in general.

- **Mass Balance Markers**. Coprostanol (fecal sterol) and Caffeine, and /or its metabolite 1,7-dimethylxanthine, though not toxic, would be good markers for mass balance study to underscore and verify the dilution models and confirm that materials from wastewaters are not cumulative in coastal waters, sediments or shellfish (such as mussels). Mass marker data could be combined and compared with data generated under the recommended environmental assessment and monitoring program (paragraph D, above).

7. **Establish a Science Library for Passenger Vessels Impacts**. Include all references used in developing this paper. Utilize the State library to allow ease of access by interested parties, with possible on-line access via the internet for electronic documents.

References

Mearns, A.J., M.J. Allen and M.D. Moore. 2001. The Southern California Coastal Water Research Project. 30 years of environmental research in the Southern California Bight In 1999- 2000 Annual Report, Southern California Coastal Water Research Project, Westminister, CA.

Website links:

http://www.sccwrp.org/pubs/annrpt/99-00/abst01_ar01.htm

http://www.sccwrp.org

http://www.sfei.org

http://www.oilspill.state.ak.us/gem/index.html

Section XII

Best Management Practice and Recommended Policies

Research and evaluations to date indicate that state and federal regulations for large cruise ships, which set effluent parameters and require wastewater to be discharged while ships are moving (unless these ships meet stringent effluent limits through advanced treatment), appear to effectively limit the impact of discharge on Alaska receiving waters. The Panel recognizes many people feel that "dilution is not the solution to pollution." However, the mitigating effect of the vigorous mixing action of a moving ship, combined with concentration limits for certain wastewater constituents, is quite apparent.

Nonetheless, the cruise ship industry, regulatory agencies and concerned stakeholders should continue to their work to further minimize potential adverse impacts. Research and enhanced monitoring is important and the areas of interest to the Panel are described in Sections X and XI. But in addition to the enforcement of current regulations and continued improvements in monitoring and data collection, certain new best management practices and policies may be effective in reducing impacts. These have been identified and justified in various sections of this report. For the sake of clarity and organization, they are collected and presented here.

Wastewater discharge while underway (Section I & VII)

The current requirements for large cruise ships – wastewater discharge at a minimum speed of 6 knots and at least 1 nautical mile from shore unless they can meet the strict effluent standards for stationary discharge – is good management practice and should be practiced by all passenger ships. The Panel recognizes the difficulty of holding wastewater on board small passenger vessels until the wastewater can be discharged underway. Space is limited on board these vessels, both for wastewater storage and for installation of advanced treatment technology. However, the small cruise vessel industry should continue to energetically research various options and practices, particularly so they may avoid discharge in embayments and fjords.

Policies to prevent over-chlorination

Advanced sewage treatment technologies have been shown to be largely effective for large modern cruise ships. Smaller cruise ships, including Alaska Marine Highway System ferries, have demonstrated that the macerator/chlorinator system can treat wastewater to meet fecal coliform bacteria and total suspended solids standards. However, this is achieved by the use of dilution and high levels of chlorine. Chlorine is an effective disinfectant but excessive chlorine residual is toxic to marine life. The State of Alaska should consider whether a residual chlorine standard is necessary to prevent excessive chlorine entering the marine environment.

Best Management Practices for Large Cruise Ships with Advanced Wastewater Treatment

USCG regulations allow large cruise ships to discharge in any location and at anytime provided their effluent meets the following standards: a geometric mean of 20 fc/100 ml, with not more than 10% of the samples greater than 40 fc/100 ml; a chlorine residual not to exceed 10 mg/l and BOD and pH as specified in the Code of Federal Regulations[41]. Installation and employment of advanced treatment is encouraged. In addition, continuous discharge of effluent that meets these stringent standards avoids the possibility of re-contamination in holding tanks. Holding tanks have high levels of bacteria and would contaminate treated wastewater.

However, cruise ships discharging in port or at anchor should ensure the residual chlorine in the effluent is low and that discharge does not occur within 0.5 mile of commercial shellfish beds.

The Alaska Water Quality standard for chlorine is 2 µg/l. Effluent with 10 mg/l chlorine residual would require a 5000:1 dilution, which would be difficult if not impossible for a cruise ship at rest to achieve. Accordingly, in order to protect sensitive species near shorelines and other locations, effluents with residual chlorine concentrations above 0.2 mg/l should avoid stationary discharge[42].

Prohibiting discharge within 0.5 mile of shellfish beds relates to the protection of human health. Because there are many chemicals, (e.g. drugs and endocrine disrupters) and possibly viruses, discharged in all effluents, including those from advanced treatment systems, minimizing these elements from reaching any shellfish that are a human food source is recommended. At a distance of 0.5 mile or more, ships will probably be under way, and the effluents will experience considerable dilution. A vessel closer than 0.5 miles from shore should hold wastewater if possible until again under way. In-port discharge should not be a concern with regard to shellfish. Shellfish harvest for human consumption near ports is not recommended and often prohibited, since bacteria sources are numerous.

[41] 40 CFR 133.102
[42] Appendix 8, which discussed whole effluent toxicity tests, estimated that ships discharging at rest would achieve a dilution factor of 50 within several meters of the vessel's discharge port. 50 X 0.2 µg/l = 0.1 mg/l

Appendix I
Development and Use of an Assessment Framework

Development and Use of an Assessment Framework

Alan Mearns

The Panel's Charge and Information Provided

The primary mission of the Science Advisory Panel is to provide an objective basis for making decisions about passenger vessel wastewater discharges in order to protect marine resources and their uses in Alaska.

Shortly following its formation (February 2001), the Panel was provided a list of concerns and areas of interest developed by the Alaska Cruise Ship Initiative[43]. The Panel was also given some preliminary information on passenger vessel treatment and disposal of wastewater. Stakeholder concerns included aquatic toxicity, seafood contamination, and cumulative environmental effects. The assumption was that resources were at risk from current practices.

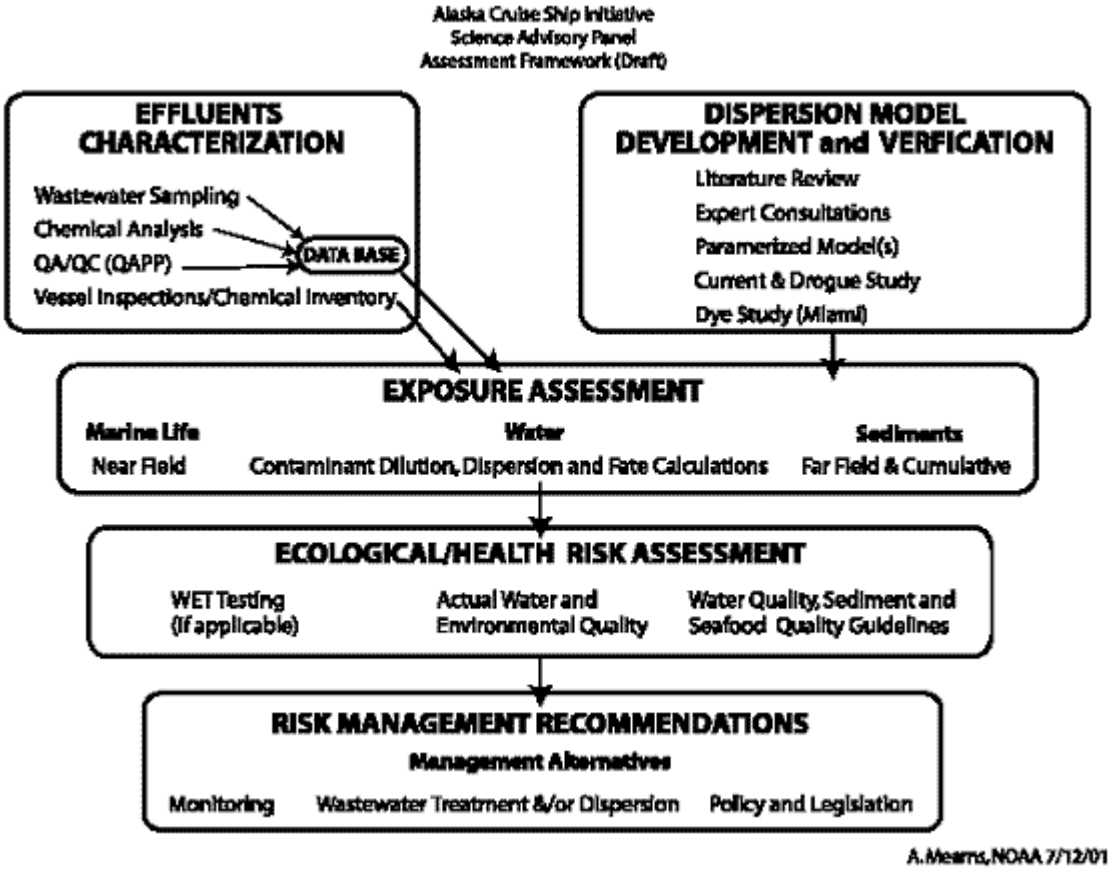
A Risk Assessment/Risk Management Framework

The Panel quickly realized that the concerns and questions could only be addressed by following a step-wise process that addressed connections between wastewater quality, treatment and disposal, and resources at risk in the marine environment. We chose to adopt elements of a framework based on the basic concepts of risk assessment. Principles of risk assessment require defining resources at risk, the hazard that creates the risk, and the probability of a negative outcome when the resource is exposed. The full process allows the opportunity to quantify risk as well as identify uncertainty. From this information, the success of existing management and policy actions could be measured and the need for addition actions, if any, objectively addressed.

The Panel's risk-based Framework is shown in the flow diagram in Figure 1 and is described in more detail below. The three central boxes represent the core of this framework:

(1) Exposure Assessment,
(2) Ecological/Health Risk Assessment and
(3) Risk Management Recommendations.

[43] The Alaska Cruise ship Initiative was a voluntary effort commissioned by the Commissioner of the Alaska Department of Environmental Conservation In December 1999. The Initiative, composed of state and federal agencies, the cruise ship industry, concerned stakeholders, and environmental protection advocacy groups, worked to characterize the quality and quantity of wastewater discharge, set initial voluntary best management practice and keep the public informed. The Alaska Cruise Ship Initiative completed its work in December 2001.



Exposure Assessment

The goal of **Exposure Assessment** is to estimate and/or measure expected concentrations of pollutants, and their temporal and spatial extent, in the water as a result of discharges from the ships.

This requires two basic kinds of information: (a) amounts of materials in discharged wastewater effluents, and from other sources or pathways (upper left box), and (b) the extent to which the wastewaters are mixed and dispersed into the water from moving and non-moving ships (upper right box). Wastewater concentration data and mixing information are not ends in themselves, but necessary inputs to **Exposure Assessment**. Exposure Assessment is a necessary input to evaluating Risk.

To quantify expected environmental concentrations we had to: (a) carefully analyze what is discharged (effluent characterization) and (b) how the wastewater and its materials are distributed in the environment once discharged (dispersion model development and verification). Wastewater sampling commissioned by the USCG and ADEC in 2000 and 2001 provided abundant information. However, we also had to address critical questions about the effluent characterization that included: adequacy and quality of the process of wastewater sampling, completeness and of the chemical and microbiological analyses, and identification of all pathways by which they could enter the water.

Meanwhile, to determine pollutant concentrations in the water following discharges, our oceanographers took a hard, independent look at existing discharge configurations, dilution and dispersion models, and actual measures of the dispersion and fate of discharged material. These efforts gave us tools and independent crosschecks to estimate contaminant concentrations in the paths of discharging vessels. They also made a strong case for participating in and making effective use of effluent dye dispersion measurements that were about to be conducted by EPA in Florida. These actions resulted in our best estimates of expected environmental concentrations of pollutants in the water, during and following discharge events, including our preliminary estimates of cumulative exposure concentrations.

Ecological and Human Health Risk Assessment

Once we understood the range of actual or expected environmental concentrations of chemical and microbial pollutants in the water, we could proceed with evaluating risks to marine life and humans exposed to those concentrations. Pollutant concentrations were compared to existing state and federal water, sediment, and seafood quality criteria and guidelines. Any exceedances of these criteria and guidelines were identified and flagged for evaluation. However we took several additional approaches as well. We argued successfully to conduct limited, but well-selected, whole effluent toxicity testing (WET) with sensitive life stages of marine organisms, the results of which would allow us to make independent objective statements about the risks of toxicity to marine life. We also looked at the potential for accumulation of bacteria and chemicals in marine life and sediments and sought out limited data on concentrations of contaminants actually in sediments and organisms in the area of concern. From this we could make preliminary objective statements about the probability of impacts to marine resources in the water, on the sea floor, and along the shoreline, both from individual discharge events and from cumulative discharges.

Risk Management Recommendations

Our assessment is not complete, but enough has been done to provide some initial guidance. Armed with clear and supported statements about expected or actual impacts, the Panel was able to make some preliminary comment on the effectiveness of existing regulations in protecting resources and public health. In addition, the Panel has been able to address the benefits, if any, of additional actions and remaining uncertainties that require additional investigation, sampling and monitoring.

This simple framework provided the Panel with a "road map" that:

1. Lead directly from information gathering to management:
2. Allowed us to use our limited resources to strike a balance among two critical actions (defining exposure and then defining risk from that exposure):
3. Gave us focus for effectively using existing and incoming data and information; and
4. Provided early opportunity to request the collection of new information needed to resolve the most important uncertainties.

It also prevented the Panel from spending too much of its limited resources and time on any one piece of the process, or being overtly diverted by single issues.

Communicating the Results

Ideally the chapters in this report would be organized according to the Framework. However, we thought it would be more effective to report our findings in terms of some of the initial specific issues such as dilution, wastewater quality, fate of bacteria, sea surface micro-layer impacts, sediments, etc. That is the way this report is organized. Within most sections the reader will see the elements of the framework and process of risk assessment in action.

As an uncompensated, volunteer advisory group, the panel did not have the time or resources to develop and conduct a detailed risk assessment process. However, the framework followed the basic principles of risk assessment and served as an efficient guide to producing a quite complex, multi-component assessment.

Appendix 2
Dilution – Calculated Priorty Pollutant Concentration in Ambient Marine Water

A1. Estimated maximum and average concentrations attributable to detected priority pollutants in cruise ship waste water discharges after initial dilution, compared with Alaska's surface water quality standards for toxicants[44] (Analysis of graywater and treated blackwater from 21 cruise ships, 2000)

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
Volatiles by GC/MS						
Chloromethane	95/9	5.0	240	6.43	0.02/0.0005	None
Vinyl Chloride	95	2.0	Not detected			
Chloroethane	95	5.0	Not detected	Not detected		
1,1-Dichloroethene	95	2.0	Not detected	Not detected		
Methylene Chloride	95	5.0	Not detected	Not detected		

[44] State-adopted aquatic life criteria will be shown unless there are no aquatic life criteria available. If not, federally promulgated criteria [National Toxics Rule(NTR)] may be shown that may include human health criteria. Chronic criteria are applied to ambient waters of the state. If acute criteria are shown, then there are no chronic criteria available.
[45] An acute criterion is the highest concentration of a pollutant to which aquatic life can be exposed for a short period of time (i.e., 1-hour, based on exposure to the average concentration) without deleterious effects.
[46] A chronic criterion is the highest concentration of a pollutant to which aquatic life can be exposed for an extended period of time (i.e., 4-day average) without deleterious effects. Human health criteria are also applied as chronic (70 year exposure to the chronic pollutant level, for the average lifetime of a human).

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
trans-1, 2-Dichloroethene	95	2.0	Not detected	Not detected		
1,1-Dichloroethane	95	2.0	Not detected	Not detected		
Chloroform	95/81	2.0	1500	48.3	0.03/0.0001	None
1,1,1-Trichloroethane	95	2.0	Not detected	Not detected		
Carbon Tetrachloride	95/12	2.0	27	0.53	Negligible	50,000 (acute)
Benzene	95	2.0	Not detected	Not detected		
1,2-Dichloroethane	95/10	2.0	1.9	0.09	Negligible	113,000 (acute)
Trichloroethene	95/5	2.0	71	0.87	0.001/0.00002	
Toluene	95/13	2.0	5.1	0.22	Negligible	5000 (chronic)
trans-1,3-Dichloropropene	95	2.0	Not detected	Not detected		
1,1,2-Trichloroethane	95	2.0	Not detected	Not detected		

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
Tetrachloroethene(or tetrachloroethylene)	95/13	2.0	740	13.2	0.014/0.0002	450(chronic)
Dibromochloromethane	95/42	2.0	93	11.8	Negligible	6400(chronic)
Chlorobenzene	95	2.0	Not detected	Not detected		
Ethylbenzene	95/14	2.0	4.7	0.21	Negligible	430(acute)
Bromoform	95/41	2.0	170	12.2	0.004/0.0002	No aquatic life criteria 3,600(NTR human health criteria)
1,1,2,2-Tetrachloroethane	95	2.0	Not detected	Not detected		
Acrylonitrile	95	10	Not detected	Not detected		
2-Cholorethyl Vinyl Ether	95	10	Not detected	Not detected		

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
Semivolatile Organics						
N-Nitrosodimethylamine	48	5.0	Not detected	Not detected		
Phenol	48/11	5.0	250	12.05	0.005/0.0002	5800(acute)
bis(2-Chloroethyl) ether	48	5.0	Not detected	Not detected		
2-Chlorophenol	48	5.0	Not detected	Not detected		
1,3-Dichlorobenzene	48/1	5.0	380 (one detect)	7.9	Negligible	1970(acute)
1,4-Dichlorobenzene	48/7	5.0	350	7.7	0.007/0.0001	1970(acute)
1,2-Dichlorobenzene	48/1	5.0	390 (one detect)	8.12	Negligible	1970(acute)
Bis (2-Chloroisopropyl) ethe	48	5.0	Not detected	Not detected		
n-Nitroso-di-n-propylamine	48	5.0	Not detected	Not detected		

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
Hexachloroethane	48	5.0	Not detected	Not detected		
Nitrobenzene	48	5.0	Not detected	Not detected		
Isophorone	48	5.0	Not detected	Not detected		
2-Nitrophenol	48/1	5.0	5.4 (one detect)	0.11	Negligible	4850(acute)
2,4-Dimethylphenol	48	25	Not detected	Not detected		
bis(2-Chloroethoxy)methane	48	5.0	Not detected	Not detected		
Naphthalene*	48/1	10	3.0 (one detect)	0.06	Negligible	2350(acute)
Hexachlorobutadiene	48	5.0	Not detected	Not detected		
4-Chloro-3-methylphenol	48	5.0	Not detected	Not detected		
Hexachloro-cyclopentadiene	48	10	Not detected	Not detected		

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
2, 4, 6-Trichlorophenol	48/2	5.0	3.2	0.08	Negligible	No aquatic life criteria 65 (NTR human health criteria)
2-Chloronaphthalene	48	5.0	Not detected	Not detected		
Dimethylphthalate	48/1	5.0	1.1 (one detect)	0.023	Negligible	3.4 (chronic)
Acenaphthylene*	48	5.0	Not detected	Not detected		
Acenaphthene*	48/1	5.0	7.7 (one detect)	0.16	Negligible	710(chronic)
2,4-Dinitrophenol	48	70	Not detected	Not detected		
4-Nitrophenol	48/1	5.0	8.0 (one detect)	0.17	Negligible	4850(acute)
2,6-Dinitrotoluene	48	5.0	Not detected	Not detected		
2,4-Dinitrotoluene	48	5.0	Not detected	Not detected		
Diethylphthalate	48/23	5.0	27.0	2.12	0.0005/0.00002	3.4(chronic)
4-Chlorophenyl-	48	5.0	Not detected	Not detected		

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
phenylether						
1,2-Diphenyl hydrazine	48	5.0	Not detected	Not detected		
4-Bromophenyl-phenylether	48	5.0	Not detected	Not detected		
Hexachlorobenzene	48	5.0	Not detected	Not detected		
Pentachlorophenol	48	5.0	Not detected	Not detected		
Phenanthrene*	48/2	5.0	3.1	0.13	Negligible	None
Anthracene*	48	5.0	Not detected	Not detected		
Di-n-butylphthalate	48/11	5.0	20	1.57	0.06/0.00002	3.4(chronic)
Fluoranthene*	48/1	5.0	1.2 (one detect)	0.03	Negligible	16(chronic)
Benzidine	48	90	Not detected	Not detected		
Pyrene*	48	5.0	Not detected	Not detected		
Butylbenzylphthalate	48/6	5.0	9.6	0.34	Negligible	None

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
3,3'-Dichlorobenzidine	48	10	Not detected	Not detected		
Benzo(a)Anthracene*	48	5.0	Not detected	Not detected		
Chrysene	48	5.0	Not detected	Not detected		
Benzo(b)fluoranthene*	48	5.0	Not detected	Not detected		
Benzo(k)fluoranthene*	48	5.0	Not detected	Not detected		
Dibenz(a,h)anthracene*	48	5.0	Not detected	Not detected		
Benzo(g,h,i)perylene*	48	5.0	Not detected	Not detected		
Metals						
Antimony	48	variable	Not detected	Not detected		
Arsenic	48	variable	Not detected	Not detected		
Cadmium	48/3	variable	0.35	0.024	Negligible	9.3(chronic)
Chromium (total)	48/18	variable	53.0	7.32	0.001/0.0001	50()(VI) (chronic)

MATERIAL	Number of samples analyzed/ Number of samples material detected	DETECTION LIMIT µg/liter (approx. ppb)	Maximum concentrations detected in graywater and/or treated blackwater discharge* (µg/liter or ppb)	Average Concentration (µg/liter or ppb)	Waste concentrations (µg/liter) after dilution, <15 minutes (dilution factor 50,000) Maximum/ Average	State Criteria for Marine Waters (µg/liter) ACUTE[45] or CHRONIC[46]
Copper	48/23	20	7100	789.6	0.14/0.016	2.9(acute)
Beryllium	48	1.0	Not detected	Not detected		
Nickel	48/15	40	630	33.8	0.01/0.0007	8.3(chronic)
Zinc	48/23	5.0	1800	537.6	0.036/0.009	86 (chronic)
Lead	48/14	7.5	250	15.1	0.005/0.0002	5.6(chronic)
Mercury	48/3	0.20	0.67	0.007	0.00001/ Negligible	0.025(chronic)
Selenium	48	3.0	Not detected	Not detected		
Silver	48/18	0.15	7.5	0.73	0.0001/0.00001	2.3(acute)
Thallium	48	15	Not detected	Not detected		
Cyanide, Total	48/5	10	73 (interferences?)	Interference?	0.005	1.0 (acute) (measure as free cyanide)

Appendix 3
Sampling Design

Charles McGee

In any experiment there is a logical flow of emphasis. This flow moves from purpose, to hypothesis testing, to sampling design, to data gathering, to statistical review and finally to interpretation of results. This paper discusses the sampling of cruise ship holding tanks for the purpose of determining the presence and concentration of contaminants that would be of concern if discharged into Alaska waters.

The design of a sampling protocol requires careful thought be given to the potential variables that would influence the interpretation of the measurements. Statistical methods can cope with random errors, but statistics will not eliminate the influence of systematic errors (bias) on the measurements upon which findings will be based (Colquhoun 1971). Questions like does the design really measure what is wanted to be learned, and is the cost and time necessary for those measurements reasonable (Green, 1979).

Of course, the best sample is the whole item. However, this is typically not feasible due to the item's size or location or the laboratory's size location or analytical abilities. As a result, small portions of the whole must be collected and the analytical results extrapolated back to the whole.

The simplest form of sampling is to collect grab samples. The goal of collecting grab samples is to collect enough parts of the whole to eventually understand the whole. Grab samples are limited to a single time and location, and usually, many grab samples must be collected and analyzed over a period of time before the results can then be averaged to make extrapolations back to the whole.

Multiple sampling builds on the grab-sampling concept. In multiple sampling, sampling can be either sequential or composite. Sequential sampling is based upon obtaining a standard size while holding constant one of the domains of sample per unit of time, per unit flow or per unit distance from one sampling point to the next. Composite sampling reflects collecting sequential samples under a variety of domains, mixing the grab samples together to form a well-mixed composite and then sub-sampling the mixture. Values in the sub-samples can then be averaged and extrapolated back to the whole.

The most complete sampling scheme is the integrated sample, which uses a variety of all the methods of sampling (Smith, 1999).

References:

Colquhoun, D., *Lectures on biostatistics.* Clarendon Press, 1971.

Green, R. H., Sampling Design and Statistical Methods for Environmental Biologists, John Wiley & Sons, 1979.

Smith, R-K., Handbook of Environmental Analysis, Fourth Edition, Genium Publishing Corporation, 1999

Appendix 4
Priority Pollutant List

LIST OF PRIORITY POLLUTANTS

Note: The complete EPA list of pollutants with public health and marine aquatic criteria can be viewed at:

http://www.epa.gov/waterscience/pc/revcom.pdf

Estimated Concentration of Priority Pollutants

PCBs (Organochlorine)			
Aroclor-1016	Aroclor-1242	Aroclor-1254	Decachlorobiphenyl
Aroclor-1221	Aroclor-1248	Aroclor-1260	Tetrachlorometaxylene
Aroclor-1232			

Volatile Organic Compounds (VOCs)		
1,1,1,2-Tetrachloroethane	2-Hexanone	Hexachlorobutadiene
1,1,1-Trichloroethane	4-Chlorotoluene	Iodomethane
1,1,2,2-Tetrachloroethane	4-Isopropyltoluene	Isopropylbenzene
1,1,2-Trichloroethane	4-Methyl-2-Pentanone	m&p Xylenes
1,1-Dichloroethane	Acetone	Methylene Chloride
1,1-Dichloroethene	Acrylonitrile	Naphthalene
1,1-Dichloropropene	Benzene	n-Butylbenzene
1,2,3-Trichlorobenzene	Bromobenzene	n-Propylbenzene
1,2,3-Trichloropropane	Bromochloromethane	O-Xylene
1,2,4-Trichlorobenzene	Bromodichloromethane	p-Bromofluorobenzene
1,2,4-Trimethylbenzene	Bromoform	sec-Butylbenzene
1,2-Dibromo-3-Chloropropane	Bromomethane	Styrene
1,2-Dibromoethane	Carbon Disulfide	tert-Butyl Methyl Ether
1,2-Dichlorobenzene	Carbon Tetrachloride	tert-Butylbenzene
1,2-Dichloroethane	Chlorobenzene	Tetrachloroethene

PCBs (Organochlorine)		
1,2-Dichloroethane-d4	Chloroethane	Toluene
1,2-Dichloropropane	Chloroform	Toluene D-8
1,3,5-Trimethylbenzene	Chloromethane	trans-1,2-Dichloroethene
1,3-Dichlorobenzene	Cis-1,2-Dichloroethene	trans-1,3-Dichloropropene
1,3-Dichloropropane	Cis-1,3-Dichloropropene	trans-1,4-Dichloro-2 Buten
1,4-Dichlorobenzene	Dibromochloromethane	Trichloroethene
2,2-Dichloropropane	Dibromofluoromethane	Trichlorofluoromethane
2-Butanone	Dibromomethane	Trichlorotrifluoroethane
2-Chloroethyl Vinyl Ether	Dichlorodifluoromethane	Vinyl Acetate
2-Chlorotoluene	Ethylbenzene	Vinyl Chloride

Trace Metals (total recoverable and dissolved)			
Antimony	Chromium	Mercury	Silver
Arsenic	Copper	Nickel	Thallium
Beryllium	Lead	Selenium	Zinc
Cadmium			

Base Neutrals and Acids (includes QA/QC analytes)			
1,2,4-Trichlorobenzene	2-Nitrophenol	Benzo(b)fluoranthene	Di-n-Butylphthalate
1,2-Dichlorobenzene	3&4-Methylphenol	Benzo(g,h,i)perylene	Di-n-Octylphthalate
1,3-Dichlorobenzene	3,3'-Dichlorobenzidine	Benzo(k)fluoranthene	Fluoranthene
2,4,5-Trichlorophenol	3-Nitroaniline	Benzoic Acid	Fluorene
2,4,6-Tribromophenol	4,6-Dinitro-2-Methylphenol	Benzyl Alcohol	Hexachlorobenzene
2,4,6-	4-Bromophenyl-	Bis (2-Chloroethoxy)	Hexachlorobutadiene

PCBs (Organochlorine)			
Trichlorophenol	Phenylether	Methane	
2,4-Dichlorophenol	4-Chloro-3-Methylphenol	Bis (2-chloroisopropyl) ether	Hexachlorocyclopentadiene
2,4-Dimethylphenol	4-Chloroaniline	Bis(2-Chloroethyl) Ether	Hexachloroethane
2,4-Dinitrophenol	4-Chlorophenyl methylsulfone	Bis(2-Ethylhexyl)Phthalate	Indeno(1,2,3-cd)pyrene
2,4-Dinitrotoluene	4-Chlorophenyl-Phenylether	Butylbenzylphthalate	Isophorone
2,6-Dinitrotoluene	4-Nitroaniline	Chrysene	Naphthalene
2-Chloronaphthalene	4-Nitrophenol	D14-Terphenyl	Nitrobenzene
2-Chlorophenol	Acenaphthene	D5-Nitrobenzene	N-Nitroso-Di-N-Propylamine
2-Fluorobiphenyl	Acenaphthylene	D6-Phenol	N-Nitrosodiphenylamine
2-Fluorophenol	Anthracene	Dibenzo(a,h)anthracene	Pentachlorophenol
2-Methylnaphthalene	Benzidine	Dibenzofuran	Phenanthrene
2-Methylphenol	Benzo(a)anthracene	Diethylphthalate	Phenol
2-Nitroaniline	Benzo(a)pyrene	Dimethylphthalate	Pyrene

Appendix 5
Small Ship Data

Table B1: Small Ship 2001 and 2002 Alaska Marine Highway Conventional Data Comparison

Ship Name	Date MDL	Ammonia mg/l 0.016	pH 0.1	BOD mg/l 1.0	COD mg/l 3.7	TSS mg/l 0.1	Total Cl mg/l 0.1	FREE CL mg/l 0.1	FECAL MPN/100ml 2	CONDUCT umhos/cm 1.0
Columbia	13-Aug-01	Not analyzed	Not analyzed	84.2	765	111	1.5	0.7	1100	34400
Columbia	13-Aug-01	Not analyzed	7.5	89.3	744	118	1	0.5	1300	34700
Columbia	13-Aug-01	Not analyzed	7.5	80.6	863	105	1.2	0.6	500	34700
Kennicott	11-Dec-00	Not analyzed	7.1	3.5	not analyzed	43	3.5	3	5	not analyzed
Kennicott	01-Apr-02	Not analyzed	7.04	246	1180	0.5	0.05	0.05	9000000	36000
Malaspina	02-Jul-01	1.4	7.9	20	470	40	0.05	0.05	70000	34800
Matanuska	09-Apr-01	22	7.3	150	not analyzed	73	0.2	0.05	2200	not analyzed
Matanuska	18-Dec-01	not analyzed	7.38	110	608	69.7	3.1	0.05	2	35900
Matanuska	25-Feb-02	not analyzed	7.5	154	1240	73.7	5	0.05	50000	35500
Kennicott	1-Apr-02	12	7.04	246	1,180	179	0.05	0.05	9,000,000	36,400
Matanuska	25-Feb-02	16.8	7.5	154	1,240	73.7	5	0.05	50,000	35,500
Kennicott	25-Jun-02	0.008	8.02	0.5	1,200	32	2	2	14	37,000
Malaspina	26-Jun-02	10.1	6.99	88.8	876	100	4	3.5	5	28,300
Columbia	22-Jul-02	29.4	7.67	117	495	73.9	20	12	22	22800
Kennicott	10-Jul-02	0.008	8.1	0.5	870	22.5	40	25	1	31200
Malaspina	9-Jul-02	0.121	7.91	0.5	514	22.9	3.5	2.5	1	23800
Matanuska	20-Jul-02	1.27	6.88	134	451	75.2	25	10	1	23000

Table B2: Small Ships Treated Blackwater Conventional Pollutants

2001 data (no** samples **taken in 2000)

Treatment Type	Ammonia Mg/L	pH	BOD mg/l	COD mg/l	TSS mg/l	Total Cl mg/l	FREE CL mg/l	FECAL MPN/100ml	CONDUCT umhos/cm
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**0.1**	**2**	**1.0**
Macerator-CL	not analyzed	7.56	0.5	509	32	3.5	0.05	33	not analyzed
Macerator-CL	not analyzed	7.78	0.5	778	28.2	0.05	0.05	110	not analyzed
Macerator-CL	not analyzed	not analyzed	not analyzed	not analyzed	83.5	0.05	0.05	5	not analyzed
Macerator-CL	3.2	7.5	25	1100	97	0.55	0.3	50	not analyzed
Macerator-CL	not analyzed	7.34	161	1820	333	11	7	70	37400
Macerator-CL	not analyzed	Not analyzed	0.5	not analyzed	7	0.05	0.05	17	not analyzed
Macerator-CL	not analyzed	8.1	19.1	697	48.8	3.5	0.4	130	not analyzed
Macerator-CL	not analyzed	7.9	6.02	644	25.8	1.5	0.9	1	not analyzed
Macerator-CL	not analyzed	6.4	318	1470	638	0.3	0.1	2400000	not analyzed
Macerator-CL	not analyzed	7.5	585	1240	880	0.05	0.05	16000000	not analyzed
Macerator-CL	not analyzed	7.9	5.09	982	72.2	2.1	0.8	300	not analyzed
Macerator-CL	not analyzed	7.99	24.3	863	89.6	0.05	0.05	500000	not analyzed
Macerator-CL	not analyzed	7.99	264	1160	421	0.05	0.05	500000	not analyzed
Biological	310	8	599	1650	216	0.05	0.05	1100000	not analyzed
Min	**3.2**	**6.4**	**0.5**	**509**	**7**	**0.05**	**0.05**	**1**	**37400**
Max	**310**	**8.1**	**585**	**1820**	**880**	**11**	**7**	**16000000**	**37400**
GeoMean	**31.50**	**7.65**	**21.51**	**1004.25**	**97.57**	**0.30**	**0.15**	**1545.79**	**37400**

NOTES: The biological system does not perform as well as the average macerator chlorinating units but only one point is available.

8 ships have fecal coliform counts below 130, one ship is at 300 and 5 are over 500,000.

Table B3: Small Ships Black and Graywater mixed and treated Conventional Pollutants

2001 and 2002 data (no samples taken in 2000)

	Sample Date	Ammonia Mg/L	pH	BOD mg/l	COD mg/l	TSS mg/l	Total Cl mg/l	FREE Cl mg/l	Fecal Coliform MPN/100ml	CONDUCT Umhos/cm
Treatment Type	**MDL**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**0.1**	**2**	**1.0**
Macerator/Cl	13-Aug-01	Not analyzed	7.5	89.3	744	118	1	0.5	1300	34700
Macerator/Cl	13-Aug-01	Not analyzed	7.5	80.6	863	105	1.2	0.6	500	34700
Macerator/Cl	11-Dec-00	Not analyzed	7.1	3.5	not analyzed	43	3.5	3	5	not analyzed
Macerator/Cl	01-Apr-02	Not analyzed	7.04	246	1180	0.05	0.05	0.05	9000000	36000
Macerator/Cl	02-Jul-01	1.4	7.9	20	470	40	0.05	0.05	70000	34800
Macerator/Cl	09-Apr-01	22	7.3	150	not analyzed	73	0.2	0.05	2200	not analyzed
Macerator/Cl	18-Dec-01	Not analyzed	7.38	110	608	69.7	3.1	0.05	2	35900
Macerator/Cl	25-Feb-02	Not analyzed	7.5	154	1240	73.7	5	0.05	50000	35500
Macerator/Cl	09-Aug-01	Not analyzed	7.2	580	1340	1030	0.8	0.1	9000	not analyzed
Macerator/Cl	23-Aug-01	Not analyzed	6.25	2080	2850	1200	0.05	0.05	16000000	not analyzed
Macerator/Cl	17-Sep-01	Not analyzed	5.54	1310	1850	146	0.05	0.05	16000000	not analyzed
Macerator/Cl	1-Apr-02	12	7.04	246	1,180	179	0.05	0.05	9000000	36400
Macerator/Cl	25-Jun-02	0.008	8.02	0.5	1,200	32	2	2	14	37000
Macerator/Cl	26-Jun-02	10.1	6.99	88.8	876	100	4	3.5	5	28300
Macerator/Cl	25-Feb-02	16.8	7.5	154	1240	73.7	5	0.05	50,000	35500
Macerator/Cl	22-Jul-02	29.4	7.67	117	495	73.9	20	12	22	22800
Macerator/Cl	10-Jul-02	0.008	8.1	0.5	870	22.5	40	25	1	31200
Macerator/Cl	9-Jul-02	0.121	7.91	0.5	514	22.9	3.5	2.5	1	23800
Macerator/Cl	20-Jul-02	1.27	6.88	134	451	75.2	25	10	1	23000
	MIN	**0.0.008**	**5.54**	**3.5**	**451**	**22.5**	**0.2**	**0.1**	**1**	**22800**
	MAX	**29.4**	**8.1**	**2080**	**2850**	**1200**	**40**	**25**	**16000000**	**37000**
	GeoMean	**1.34**	**7.25**	**58.08**	**930.01**	**61.14**	**1.12**	**0.38**	**1414**	**31653**

Table B4: Small Ships Graywater Mixed Conventional Pollutants

2001 and 2002 data (no samples taken in 2000)

Treatment Type	Ammonia Mg/L	pH	BOD mg/l	COD mg/l	TSS mg/l	Total Cl mg/l	FREE CL mg/l	FECAL MPN/100ml	CONDUCT umhos/cm	Comments
MDL	0.016	0.1	1.0	3.7	0.1	0.1	0.1	2	1.0	
Chlorine	not analyzed	7.8	not analyzed	901	316	180	180	1	Not analyzed	Holding tank
Chlorine	not analyzed	8.2	430	1370	372	270	150	50	Not analyzed	Holding tank
Chlorine	not analyzed	8	395	674	78.6	0.05	0.05	30000	not analyzed	Holding tank
Chlorine	not analyzed	7.6	330	722	132	10	7.5	1	not analyzed	Holding tank
None	not analyzed	Not analyzed	74.5	not analyzed	106	0.05	not analyzed	16000000	not analyzed	None
None	not analyzed	Not analyzed	62.9	not analyzed	28	0.05	not analyzed	1680	not analyzed	None
None	not analyzed	7.33	2.79	25.3	5.73	0.05	not analyzed	1	46.8	None
None	not analyzed	7.25	115	225	44.4	0.05	not analyzed	1300000	60.3	None
None	not analyzed	7.98	205	472	83.6	0.05	0.05	300000	not analyzed	None
None	not analyzed	7	372	578	143	0.05	0.05	11000	not analyzed	None
None	not analyzed	Not analyzed	60	not analyzed	28	0.05	0.05	1680	not analyzed	
None	7.29	7.18	94.4	106	47.7	0.05	0.05	3000	not analyzed	None
None	not analyzed	5.39	1010	860	269	0.05	0.05	16000000	not analyzed	None
Min	7.29	5.39	2.79	25.3	5.73	0.05	0.05	1	46.8	None
Max	7.29	8.2	1010	1370	372	270	180	16000000	60.3	None
GeoMean	**7.29**	**7.33**	**135.04**	**391.71**	**78.00**	**0.27**	**0.53**	**3545**	**53.12**	**None**
GeoMean Chlorine	**Not analyzed**	**7.90**	**382.70**	**880.36**	**186.88**	**12.49**	**10.03**	**35**	**not analyzed**	**None**
GeoMean Untreated	**7.29**	**6.972**	**95.422**	**228.3**	**52.9**	**0.05**	**0.05**	**27602**	**53.123**	**None**

Table B5: Small Ships Graywater Accommodations Conventional Pollutants

2001 and 2002 data (no samples taken in 2000)

Treatment Type	Ammonia	pH	BOD	COD	TSS	T Cl	FREE CL	FECAL	CONDUCT
	Mg/L		mg/l	mg/l	mg/l	mg/l	mg/l	MPN/100ml	umhos/cm
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**0.1**	**2**	**1.0**
None	not analyzed	6.63	49.7	not analyzed	41.4	0.05	0.05	1	not analyzed
None	not analyzed	not analyzed	224.37	not analyzed	805	1.56	not analyzed	1400	not analyzed
None	not analyzed	not analyzed	208.6	not analyzed	112.5	0.36	not analyzed	1	not analyzed
None	not analyzed	not analyzed	223.17	not analyzed	17.3	0.11	not analyzed	1	not analyzed
None	not analyzed	not analyzed	309.1	not analyzed	2.7	0.05	not analyzed	1	not analyzed
None	not analyzed	not analyzed	215.57	not analyzed	59.5	0.28	not analyzed	1	not analyzed
None	not analyzed	not analyzed	112.67	not analyzed	19.5	0.13	not analyzed	1000	not analyzed
None	not analyzed	not analyzed	205.13	not analyzed	2.5	0.05	not analyzed	20	not analyzed
None	not analyzed	not analyzed	ND	not analyzed	6.5	0.02	not analyzed	1	not analyzed
None	not analyzed	6.86	109	174	22	0.05	0.05	200	not analyzed
Min	**0**	**6.63**	**49.7**	**174**	**2.5**	**0.02**	**0.05**	**1**	**0**
Max	**0**	**6.86**	**309.1**	**174**	**805**	**1.56**	**0.05**	**1400**	**0**
GeoMean	**Not analyzed**	**6.744**	**164.28**	**174**	**24.33**	**0.111**	**0.05**	**9.44**	**#NUM!**

Table B6: Small Ships Laundry Graywater Conventional Pollutants

2001 and 2002 data (no samples taken in 2000)

Treatment Type	Ammonia mg/L	pH	BOD mg/l	COD mg/l	TSS mg/l	T Cl mg/l	FREE CL mg/l	FECAL MPN/100ml	CONDUCT umhos/cm	Comments
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**0.1**	**2**	**1.0**	**Comments**
None	0.245	10.7	138	374	22.9	0.3	0.05	2	not analyzed	From holding tank
None	Not taken	7.79	110	272	20.1	0.4	0.3	1	not analyzed	From holding tank
Min	**0.245**	**7.79**	**110**	**272**	**20.1**	**0.3**	**0.05**	**1**	**not analyzed**	**None**
Max	**0.245**	**10.7**	**138**	**374**	**22.9**	**0.4**	**0.3**	**2**	**0**	**None**
GeoMean	**0.245**	**9.1298**	**123.207**	**319**	**21.45**	**0.346**	**0.175**	**1.5**	**not analyzed**	**None**

Table B7: Small Ships Galley Graywater Conventional Pollutants

2001 and 2002 data (no samples taken in 2000)

Treatment Type	Ammonia mg/l	pH	BOD mg/l	COD mg/l	TSS mg/l	T Cl mg/l	FREE CL mg/l	FECAL MPN/100ml	CONDUCT umhos/cm	Comments
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**0.1**	**2**	**1.0**	**Comments**
None	not analyzed	not analyzed	222.7	not analyzed	81.5	6	not analyzed	100	not analyzed	None
None	not analyzed	not analyzed	274.83	not analyzed	22.3	0.81	not analyzed	1	not analyzed	None
Min	**not analyzed**	**not analyzed**	**222.7**	**not analyzed**	**22.3**	**0.81**	**not analyzed**	**1**	**not analyzed**	**None**
Max	**not analyzed**	**not analyzed**	**274.83**	**not analyzed**	**81.5**	**6**	**not analyzed**	**100**	**not analyzed**	**None**
GeoMean	not analyzed	not analyzed	**247.396**	not analyzed	**42.632**	**2.205**	not analyzed	**50**	not analyzed	None

Table B8: Small Ship conventional pollutants that were taken with Priority Pollutant

Sample Type	Treatment Type	Alkalinity, Total mg/l CaCO3	Ammonia as N mg/l	BOD-5 Day mg/l	COD mg/l	Conductivity	coliform MPN/100	Free Cl mg/l	Oil &Grease	Nitrate as N mg/l	TKN mg/l	PH	Phosphorous, Total	Total Clmg/l	Total Nitrate & Nitrite as N	TOC mg/l	Total settleable solids mg/l	TSS mg/l
	MDL		0.16	1.0	0.3	1.0	2	0.1	1.0	0.019	0.1	0.1	0.22	0.1		0.3	0.1	0.1
Mixed BW&GW*	Macerator/Chlorinator	166	29.4	117	495	22800	22	12	30	0.0095	42.4	7.67	5.65	20	Not taken	419	0.23	73.9
Mixed BW&GW	Macerator/Chlorinator	79.5	1.27	134	451	23000	1	10	27	Not taken	17.6	6.88	2.38	25	Not taken	336	0.05	75.2
Mixed BW&GW	Macerator/Chlorinator	76.3	0.08	0.5	870	31200	1	25	0.5	0.0095	28.7	8.1	0.11	40	Not taken	274	0.05	22.5
Mixed BW&GW	Macerator/Chlorinator	62.3	0.121	0.5	514	23800	1	2.5	13	0.0095	0.8	7.91	0.345	3.5	Not taken	6	0.05	22.9
TBW Blackwater	Macerator/Chlorinator	116	6.32	5.47	512	34500	1	0.05	8.5	0.0095	5.7	7	2.33	0.05	Not taken	299	0.05	66.6
TGW Graywater	Chlorine	61	0.08	138	228	369	1	10	52	0.0095	0.4	8.19	0.856	16	Not taken	352	0.05	17.1

*Metals data missing from this event.

Table B9: Small Ship Priority Pollutants Metals

All units are in ug/l or parts per billion (ppb)

Type	Antimony TR	Arsenic Diss.	Arsenic TR	Cadmium TR	Chromium Diss.	Chromium TR	Copper Diss.	Copper TR	Lead Diss.	Lead TR	Nickel Diss.	Nickel TR	Selenium Diss.	Selenium TR	Silver TR	Thallium	Thallium TR	Zinc Diss.
MDL	**1.5**	**1.3**	**3.6**	**0.81**	**1.9**	**2.3**	**1.0**	**1.2**	**0.9**	**1.4**	**1.5**	**1.1**	**4.2**	**4.8**	**0.93**	**0.51**	**1.5**	**2.5**
Mixed BW&GW	0.351	35	33.6	0.4	4.18	4.96	163	339	0.45	1.35	21.2	23.2	164	109	0.6	0.255	0.415	74.9
Mixed BW&GW	0.409	50	37	0.4	4.32	2.97	119	166	1.21	6.74	16.6	14.3	171	132	0.47	1.28	0.75	71.3
Mixed BW&GW	1.55	39.4	23.2	0.4	10.3	1.54	18.7	30.7	0.45	0.528	16.6	9.8	101	94.1	0.47	0.255	0.75	67.3
TBW Blackwater	0.04	53.2	48	0.4	7.56	3.95	8.48	20.2	0.45	0.804	15.1	14.4	233	143	0.47	0.619	0.75	26.2
TGW Graywater	0.0546	0.297	0.464	0.266	0.639	0.944	84.7	173	0.294	1.62	1.77	2.55	0.601	1.17	0.47	0.255	0.121	86.9
MIN	**0.04**	**0.297**	**0.464**	**0.266**	**0.639**	**0.944**	**8.48**	**20.2**	**0.45**	**0.528**	**1.77**	**2.55**	**0.601**	**1.17**	**0.47**	**0.255**	**0.75**	**26.2**
MAX	**1.55**	**53.2**	**48**	**0.266**	**10.3**	**4.96**	**163**	**339**	**1.21**	**6.74**	**21.2**	**23.2**	**233**	**132**	**0.6**	**1.28**	**0.415**	**86.9**
GEO Mean	**0.217**	**16.123**	**14.506**	**0.369**	**3.90**	**2.43**	**48.22**	**90.40**	**0.504**	**1.44**	**10.93**	**10.36**	**52.44**	**46.88**	**0.494**	**0.421**	**0.463**	**60.62**

Non-detected dissolved antimony, dissolved cadmium, and dissolved silver.

Table B10: Small Ship Priority Pollutants PCBs

(Both shown are surrogates that were added to sample for QA) all units are in ug/l or parts per billion (ppb)

Type	Treatment Type	Decachlorobiphenyl	Tetrachlorometaxylene
Mixed BW&GW	Macerator/Chlorinating	0.086	0.2
Mixed BW&GW	Macerator/Chlorinating	0.046	0.075
Mixed BW&GW	Macerator/Chlorinating	0.072	0.073
Mixed BW&GW	Macerator/Chlorinating	0.055	0.092
TBW	Macerator/Chlorinating	0.059	0.064
TGW	Chlorine	0.015	0.049
	Min	**0.015**	**0.049**
	Max	**0.086**	**0.2**
	Median	**0.057**	**0.074**
	Average	**0.059857143**	**0.107571429**
	GeoMean	**0.049013508**	**0.082527052**

All 7 PCBs (Aroclor 1016, Aroclor 1221, Aroclor 1232, Aroclor 1242, Aroclor 1248, Aroclor 1254, and Aroclor 1260) results are non-detection.

Table B11: Small Ship Priority Pollutants Base, Neutrals and Acids

All units are in ug/l or parts per billion (ppb)

Type	Treatment Type	2,4,6-Tribromophenol	2-Fluorobiphenyl	2-Fluorophenol	3&4-Methylphenol	Benzoic Acid	Benzyl Alcohol -	Bis(2-Ethylhexyl)Phthalate	D14-Terphenyl	D5-Nitrobenzene	D6-Phenol	Diethylphthalate	Di-n-Butylphthalate	Phenol
	MDL	**Surrogates**			**1.2**	**21**	**0.58**	**0.69**	**Surrogates**			**0.55**	**1.4**	**0.88**
Mixed BW&GW	Macerator/Chlorinating	170	60	55	0.6	220	8	2.1	30	68	34	3.7	0.7	0.44
Mixed BW&GW	Macerator/Chlorinating	130	37	51	5.3	600	5.6	2.8	16	49	58	2.2	0.7	0.44
Mixed BW&GW	Macerator/Chlorinating	68	77	0.44	0.6	11.5	0.29	5.1	41	84	0.5	0.275	0.7	0.44
Mixed BW&GW	Macerator/Chlorinating	54	65	7.8	4.5	62	0.29	8	36	73	6.6	0.275	0.7	1.1
TBW	Macerator/Chlorinating	87	65	81	0.6	11.5	0.29	0.35	30	74	92	0.275	2.6	0.44
TGW	Chlorine	110	81	74	0.6	60	9	2.8	40	130	91	14	0.7	0.44
	Min	**54**	**37**	**0.44**	**0.6**	**11.5**	**0.29**	**0.35**	**16**	**49**	**0.5**	**0.275**	**0.7**	**0.44**
	Max	**170**	**81**	**81**	**5.3**	**600**	**9**	**8**	**41**	**130**	**92**	**14**	**2.6**	**2.6**
	GeoMean	**95.87**	**62.31**	**19.66**	**1.21**	**63.40**	**1.46**	**2.48**	**30.78**	**76.3**	**26.53**	**1.155**	**0.87**	**0.51**

Shaded columns are surrogate pollutants that are added to the samples

Table B12: Small Ship 2002 Priority Pollutants Volatile Organics

ALL UNITS ARE IN ug/l or parts per billion (ppb)

Type	Treatment Type	1,2,4-Trimethylbenzene	1,3,5-Trimethylbenzene	2-Butanone	4-Isopropyltoluene	Acetone	Benzene	Bromochloromethane	Bromodichloromethane	Bromoform	Bromomethane	Carbon Disulfide	Chloroethane	Chloroform	Chloromethane	Dibromochloromethane	Dibromomethane	Ethylbenzene	Iodomethane	m&p Xylenes	Naphthalene	tert-Butyl Methyl Ether	Toluene
	MDL	**0.15**	**0.23**	**0.51**	**0.11**	**1.2**	**0.18**	**0.34**	**0.23**	**0.32**	**0.76**	**0.13**	**0.36**	**0.25**	**0.29**	**0.32**	**0.21**	**0.19**	**0.42**	**0.15**	**0.098**	**0.12**	**0.25**
Mixed BW& GW	Macerator/ Chlorinating	9.9	1.9	0.255	.055	45	2.6	0.54	31	130	3.4	2.1	1.4	19	2.9	73	0.51	2.2	3.1	8	8.5	1.4	0.5
Mixed BW& GW	Macerator/ Chlorinating	0.67	0.115	8.3	2.4	47	2	0.17	8.9	89	1	4.4	0.18	5.8	4.5	30	1.4	1.3	0.21	0.55	1.2	0.06	0.125
Mixed BW& GW	Macerator/ Chlorinating	.075	0.115	0.255	0.055	4	0.09	0.17	0.135	36	0.38	0.065	0.18	0.125	0.15	1.1	0.105	0.095	0.21	0.075	0.05	0.06	0.125
Mixed BW& GW	Macerator/ Chlorinating	.075	0.115	0.255	0.055	0.6	0.09	0.17	1.6	57	1.1	0.065	0.18	0.125	1.9	8.8	0.105	0.095	0.21	0.075	0.05	0.06	0.125
TBW	Macerator/ Chlorinating	0.075	0.115	0.255	0.055	9.1	0.09	0.17	0.135	0.12	0.38	1	0.18	0.125	0.15	0.16	0.105	0.095	0.21	0.075	0.05	0.06	1.2
TGW	Chlorine	0.075	0.115	5.9	0.055	52	0.09	0.17	7.2	0.12	0.38	0.065	1.3	140	2.7	1.7	0.105	0.095	0.21	0.075	0.05	1.4	1.2
	Min	**0.075**	**0.115**	**0.255**	**0.055**	**0.6**	**0.09**	**ND**	**0.135**	**0.12**	**0.38**	**0.065**	**0.18**	**0.125**	**0.15**	**0.16**	**0.105**	**0.095**	**0.21**	**0.075**	**0.05**	**0.06**	**0.125**
	Max	**9.9**	**1.9**	**8.3**	**2.4**	**52**	**2.6**	**0.54**	**31**	**130**	**3.4**	**4.4**	**1.4**	**140**	**4.5**	**73**	**1.4**	**2.2**	**3.1**	**8**	**8.5**	**1.4**	**1.2**
	GeoMean	**0.244**	**0.184**	**0.769**	**0.069**	**8.44**	**0.264**	**0.206**	**1.87**	**9.2**	**0.768**	**0.369**	**0.352**	**1.76**	**1.07**	**4.04**	**0.21**	**0.257**	**0.33**	**0.228**	**0.197**	**0.101**	**0.335**

Nondetection results are ½ the MDL for statistical purposes

.

Appendix 6
Large Vessel Data Tables

Table C1: 2000 Large Ships Samples Evaluation of Biological Blackwater Treatment Systems

Sample Date	Sample Name	Waste Type Units	Ammonia mg/L	pH	BOD mg/L	COD mg/L	TSS mg/L	T Cl mg/L	FECAL mg/L	CONDUCT MPN/100ml	FREE CL umhos/cm
		MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
02-Aug-00	Composite	Blackwater	100	5.3	75	Not taken	236	Composite	Composite	Not taken	Composite
13-Sep-00	Composite	Blackwater	64.1	6.9	130	Not taken	650	1.5	4,410	Not taken	1.133
29-Sep-00	Composite	Blackwater	66	7.6	150	1400	1430	0.108	182,436	Not taken	0.079
29-Sep-00	Composite	Blackwater	52	7.3	250	Not taken	1480	1.5	3,504	Not taken	0.5
20-Sep-00	Composite	Blackwater	74	7.7	49	Not taken	300	0.243	18,027	Not taken	0.09
03-Aug-00	One Unit	Blackwater	520	8.4	140	Not taken	589	0.05	1,400,000	Not taken	0.05
21-Sep-00	One Unit	Blackwater	730	8.7	320	Not taken	950	0.05	700,000	Not taken	0.05
22-Sep-00	Composite	Blackwater	44	4.6	58	510	250	0.92	2.47	Not taken	0.05
25-Aug-00	Composite	Blackwater	Not taken	Missing	Not taken	Not taken	Not taken	0.05	300	Not taken	0.05
05-Aug-00	Composite	Blackwater	90.25	7.92	108.89	Not taken	231.76	0.07	387,493	Not taken	0.05
12-Aug-00	2 of 4 units	Blackwater	65.89	7.65	65.04	Not taken	407	0.05	1,100,000	Not taken	0.05
29-Aug-00	Composite	Blackwater	109	7.8	65	Not taken	330	0.42	4,650	Not taken	0.05
06-Sep-00	Composite	Blackwater	96	7.55	80	Not taken	335.5	0.56	Invalidated	Not taken	0.05
09-Aug-00	Composite	Blackwater	100	6.9	130	Not taken	1260	0.464	5,349	Not taken	0.18
20-Sep-00	Composite	Blackwater	50	7.4	140	Not taken	860	Not taken	6.7	Not taken	3.33
09-Aug-00	Composite	Blackwater	110	7.5	170	Not taken	1230	Not taken	100	Not taken	0.96
14-Sep-00	Composite	Blackwater	140	8.2	82	Not taken	280	0.05	6,300	Not taken	0.05
02-Sep-00	Unit	Blackwater	180	7.6	150	1210	200	0.05	80	Not taken	0.05
18-Sep-00	Unit	Blackwater	130	6.7	110	Not taken	300	3	1	Not taken	2
09-Sep-00	Composite	Blackwater	155	7.5	250	Not taken	980	Not taken	540	Not taken	0.54
18-Sep-00	Unit	Blackwater	17.6	7.6	146	Not taken	580	0.87	23.7	Not taken	0.125
06-Aug-00	Unit	Blackwater	160	8.5	120	Not taken	280	9	23	Not taken	0.05

Sample Date	Sample Name	Waste Type Units	Ammonia mg/L	pH	BOD mg/L	COD mg/L	TSS mg/L	T Cl mg/L	FECAL mg/L	CONDUCT MPN/100ml	FREE CL umhos/cm
		MDL	0.016	0.1	1.0	3.7	0.1	0.1	2	1	0.1
		GeoMean	104.48	7.18	104.60	845	478	0.21	18,213	Not taken	0.086
		Min	17.6	4.6	49	510	200	0.05	1	Not taken	0.05
		Max	730	8.7	320	1400	1480	9	1,400,000	Not taken	3.33

Table C2: 2000 Large Ships Mixed Blackwater and Graywater from Double Bottom Tanks

Sample Date	Waste Type	Ammonia	pH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
		mg/l		mg/l	mg/l	mg/l	mg/l	MPN/100ml	umhos/cm	mg/l
	MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
25-Aug-00	Blk/Gry DB	0.19	5	650	230	380	0.05	50000	Not taken	0.05
30-Jul-00	Blk/Gry DB	57	5.9	220	395	40	0.05	35000	Not taken	0.05
10-Sep-00	Blk/Gry RO treated	1.22	5.9	80	130	Not taken	0.05	1	Not taken	0.05
10-Sep-00	Blk/Gry RO treated,	1.24	6.1	75	130	Not taken	0.05	1	Not taken	0.05
19-Aug-00	Gry/Blk aft	8.1	7.5	110	670	130	1	4000	Not taken	0.2
19-Aug-00	Gry/blk forward	13	7.4	130	710	92	1.3	510	Not taken	0.75
29-Aug-00	Gry/Blk aft	3.7	7.8	72	135	89	1.1	30000	Not taken	0.7
29-Aug-00	Gry/Blk forward	8.5	7.6	150	135	150	1.1	60000	Not taken	0.75
05-Aug-00	Gry/Blk DB tank	17	7	110	710	55	0.05	16000000	Not taken	0.05
12-Aug-00	Gry/Blk DB tank	13	6.3	180	680	110	0.05	3000000	Not taken	0.05
06-Aug-00	Gry/Blk DB	200	8.3	250	1030	320	0.05	5000000	Not taken	0.05
	MIN	**0.19**	**5**	**72**	**130**	**40**	**0.05**	**1**	**Not taken**	**0.05**
	MAX	**200**	**8.3**	**650**	**1030**	**380**	**1.3**	**16000000**	**Not taken**	**0.75**
	GeoMean	**7.12**	**6.73**	**146.28**	**338**	**119**	**0.156**	**12824**	**Not taken**	**0.118**

Table C3: 2000 Large Ship Gray Water Mixed from Collection Tanks

Sample Date	Ammonia mg/l	pH	BOD mg/l	COD mg/l	TSS mg/l	T Cl mg/l	FECAL MPN/100ml	CONDUCT umhos/cm	FREE CL mg/l
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
07-Aug-00	3.4	7.2	81	190	67	0.05	50000	Not taken	0.05
13-Sep-00	not taken	not taken	not taken	not taken	not taken	not taken	30		not taken
02-Aug-00	1.4	6.1	1120	2060	497	0.05	350000		0.05
29-Sep-00	0.12	7.5	730	440	190	0.05	invalid		0.05
29-Sep-00	5.3	6.7	190	286	86	0.05	170000		0.05
20-Sep-00	not taken	not taken	not taken	not taken	not taken	not taken	170000		not taken
03-Aug-00	1.7	4.7	86	1250	171	0.05	1300000		0.05
21-Sep-00	2.1	6.6	180	370	110	0.05	280000		0.05
25-Aug-00	3.8	3.8	Invalidated	15700	3000	0.05	7000		0.05
22-Sep-00	1.2	7	150	410	69	0.05	70000		0.05
05-Aug-00	0.45	10.3	440	850	98	0.05	490000		0.05
05-Aug-00	0.99	6.8	89	410	37	0.2	22000		0.05
05-Aug-00	0.26	4.7	780	1160	294	0.05	9200000		0.05
05-Aug-00	0.5	6.4	170	350	57	0.1	16000000		0.05
12-Aug-00	2	9.1	150	170	67	0.05	220000		0.05
15-Aug-00	1.3	4.8	1030	1530	500	0.05	invalid		0.05
12-Aug-00	1.1	5.7	810	1190	150	0.05	1600		0.05
12-Aug-00	0.52	7.7	130	380	54	0.05	800000		0.05
29-Aug-00	2.1	7.2	130	250	51	0.05	8000		0.05
18-Sep-00	1.4	8	230	400	230	0.05	invalid		0.05
09-Sep-00	26.9	6.8	170	470	110	0.05	110000		0.05
20-Sep-00	2.9	7.6	150	290	51	1.2	invalid		0.6
09-Aug-00	not taken	7.9	40	400	62	0.05	invalid		3.5
14-Sep-00	not taken	6.6	270	360	73	0.05	2200000		0.05
Min	**0.12**	**3.8**	**40**	**170**	**37**	**0.05**	**30**		**0.05**
Max	**26.9**	**10.3**	**1120**	**15700**	**3000**	**1.2**	**16000000**		**3.5**
GeoMean	**1.41**	**6.62**	**223**	**573**	**124**	**0.06**	**118052**		**0.068**

Table C4: 2000 Large Ships Laundry Graywater

Sample Date	Sample Name	Ammonia	pH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
		mg/l		mg/l	mg/l	mg/l	mg/l	MPN/100ml	umhos/cm	mg/l
	MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
29-Aug-00	Gry laundry	0.17	7.6	120	400	39	not taken	8000		0.05
07-Aug-00	Gry laundry	0.39	10.5	70	230	4	0.85	1		0.4
22-Aug-00	Gry stbrd laundry	0.1	9.6	6.7	180	54	not taken	1		0.05
29-Sep-00	Gry laundry	not taken	not taken	not taken	not taken	not taken	0.5	not taken		not taken
20-Sep-00	Gry laundry coll. Tank	not taken	not taken	not taken	not taken	not taken	1	1		0.8
03-Aug-00	Gry laundry	3	9.2	85	300	19	0.05	700		0.05
12-Aug-00	Gry laundry room	10	3	290	1310	420	0.05	1		0.05
06-Sep-00	Gry laundry	0.008	7.6	86	270	46	0.05	1		0.05
02-Sep-00	Gry laundry	0.75	10.2	98	300	38	1	1		0.4
18-Sep-00	Gry laundry tank	not taken	not taken	not taken	not taken	not taken	0.05	30		0.05
Min		**0.008**	**3**	**6.7**	**180**	**4**	**0.05**	**1**		**0.05**
Max		**10**	**10.5**	**290**	**1310**	**420**	**1**	**8000**		**0.8**
GeoMean		**0.382**	**7.72**	**73.6**	**340**	**38**	**0.20**	**8**		**0.11**

Table C5: 2000 Large Ship Graywater Accommodations and Laundry

Sample Date	Ammonia	pH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
	mg/l		mg/l	mg/l	mg/l	mg/l	MPN/100ml	umhos/cm	mg/l
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
20-Sep-00	0.61	7.3	69	240	30	0.05	1		0.05
13-Sep-00	not found	not found	not found	not found	not found	2.8	230		0.1
25-Aug-00	45	6.7	58	not found	200	not found	1		0.4
Min	0.61	6.7	58	240	30	0.05	1		0.05
Max	45	7.3	69	240	200	2.8	230		0.4
GeoMean	5.239	6.994	63.261	240	77.460	0.374	6.127		0.126

Table C6: 2000 Large Ship Galley Graywater

Sample Date	Waste Type	Ammonia mg/l	pH	BOD mg/l	COD mg/l	TSS mg/l	T Cl mg/l	FECAL MPN/100ml	CONDUCT umhos/cm	FREE CL mg/l
	MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
06-Sep-00	Gray (Galley)	2	7.3	11	25	21	not found	not found		not found
13-Sep-00	Gray (Galley)	0.63	9.5	1210	1730	320	not found	not found		not found
13-Sep-00	Gray (Galley)	not found	Not found	not found	not found	not found	2.5	3000		0.2
29-Sep-00	Gray (Galley)	not found	Not found	not found	not found	not found	4	not found		4
03-Aug-00	Gray (Galley)	1.6	6.1	1720	1090	257	not found	not found		not found
05-Aug-00	Gray (Galley)	11	7.1	180	430	140	not found	not found		not found
29-Aug-00	Gray (Galley)	9.5	6.9	490	790	160	0.05	28000		0.05
02-Sep-00	Gray (Galley)	0.008	5.6	330	785	190	0.05	9000000		0.05
18-Sep-00	Gray (Galley)	not found	Not found	not found	not found	not found	0.05	130000		0.05
09-Sep-00	Gray (Galley)	2.37	6.8	3190	10420	4500	0.05	5		1.2
18-Sep-00	Gray (Galley)	8.2	3.7	37030	69080	29400	0.05	not found		0.05
Min		**0.008**	**3.7**	**11**	**25**	**21**	**0.05**	**5**		**0.05**
Max		**11**	**9.5**	**37030**	**69080**	**29400**	**4**	**9000000**		**4**
GeoMean		**1.547**	**6.43**	**728**	**1317**	**420**	**0.163512**	**13750**		**0.179**

Table C7: 2000 Large Ship Accommodations Graywater

Sample Date	Ammonia	pH	BOD	COD	TSS	T Cl	FECAL	CONDUCT	FREE CL
	mg/l		mg/l	mg/l	mg/l	mg/l	MPN/100ml	umhos/cm	mg/l
MDL	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**2**	**1**	**0.1**
06-Sep-00	0.88	9	500	Not found	110	not found	not found		not found
18-Sep-00	not found	not found	not found	not found	not found	0.05	1200		0.05
18-Sep-00	49	7.8	210	1340	800	1.5	9		0.05
Min	**0.88**	**7.8**	**210**	**1340**	**110**	**0.05**	**9**		**0.05**
Max	**49**	**9**	**500**	**1340**	**800**	**1.5**	**1200**		**0.05**
GeoMean	**6.567**	**8.38**	**324**	**1340**	**297**	**0.274**	**104**		**0.05**

Table C8: 2001 Accommodations Graywater Held in Double Bottom Tanks and Discharged Greater than 1 Mile from Shore going at least 6 knots.

Sample Date	Sample Name	Fecal Coliform (f.c./100 ml)	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
6/5/2001	DB11 -	invalidated	56.0	not taken	6.80	97.0	240.0	0.05	0.05	4,100.0
6/5/2001	DB4 -	invalidated	230.0	not taken	4.20	1,000.0	2,300.0	0.05	0.05	3,240.0
6/5/2001	DB8 -	invalidated	150.0	not taken	4.30	870.0	2,100.0	0.05	0.05	4,320.0
7/23/2001	DB4	invalidated	102.0	0.008	5.20	373.0	765.0	0.05	0.05	2,060.0
5/31/2001	DB11	invalidated	66.0	not taken	7.60	190.0	450.0	2.00	0.20	440.0
5/31/2001	DB4	invalidated	66.0	not taken	7.10	210.0	460.0	0.10	0.05	410.0
7/26/2001	DB 4	16,000,000	50.7	0.832	6.50	217.0	410.0	0.05	0.05	418.0
6/21/2001	DB 4P	invalidated	107.0	not taken	7.20	241.0	565.0	0.20	1.50	559.0
6/22/2001	DB 4S	600,000	67.2	not taken	6.70	182.0	382.0	0.10	1.20	867.0
8/2/2001	DB 4P	1	31.0	0.008	7.70	151.0	295.0	3.50	0.70	953.0
8/2/2001	DB 4S	1	39.2	0.008	7.30	158.0	327.0	14.00	14.00	857.0
7/10/2001	DB 4	invalidated	52.4	0.718	6.95	157.0	342.0	0.30	0.05	868.0
7/10/2001	DB 8	invalidated	240.0	0.550	6.00	750.0	1,470.0	0.30	0.05	1,040.0
6/7/2001	DB8	invalidated	54.0	not taken	7.00	250.0	510.0	0.05	0.05	401.0
8/22/2001	DB 8	16,000,000	74.6	0.109	6.30	281.0	582.0	0.30	0.05	306.0

Sample Date	Sample Name	Fecal Coliform (f.c./100 ml)	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	2	0.1	0.016	0.1	1.0	3.7	0.1	0.1	1.0
Min		1	31	0.01	4.20	97	240	0.05	0.05	306
Max		16,000,000	240	0.83	7.70	1,000	2,300	14.00	14.00	4,320
Geo Mean		10,896	77	0.08	6.36	266	573	0.21	0.15	939

Table C9: 2001 Large Ship Accommodations Graywater Collected in Small Collecting Tanks and Discharged.

Sample Date	Sample Name	Fecal Coliform (fc/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
8/21/2001	CT F	16,000,000	2880.0	1.080	5.34	4,230.0	5,650.0	0.05	0.05	173.0
6/27/2001	CT 7 PT	Invalidated	49.0	not taken	6.90	150.0	270.0	0.05	0.05	334.0
6/27/2001	CT 7 SB	Invalidated	36.0	not taken	7.00	150.0	280.0	0.05	0.05	371.0
5/24/2001	CT G	300,000	79.0	not taken	6.70	230.0	300.0	2.50	0.05	96.0
5/24/2001	CT E	300,000	38.0	not taken	6.60	130.0	200.0	3.00	2.00	100.0
7/26/2001	CT C	1	not found	1.090	9.80	487.0	825.0	4.00	3.50	441.0
5/25/2001	CT 4	22,000	22.0	not taken	7.40	130.0	220.0	3.50	0.30	470.0
5/25/2001	CT 5	350,000	56.0	not taken	7.60	170.0	300.0	1.80	0.40	270.0
5/25/2001	CT 6	33	55.0	not taken	7.50	450.0	1,200.0	2.00	0.10	430.0
9/25/2001	CT	50,000	126.0	0.892	8.97	1,340.0	2,320.0	0.90	0.05	536.0
6/5/2001	CT 3 E	170	100.0	not taken	9.20	500.0	970.0	3.50	0.30	1,080.0
6/5/2001	CT 4 D	1	22.0	not taken	7.90	100.0	250.0	70.00	50.00	4,220.0
6/5/2001	CT 6F	1	25.0	not taken	8.90	120.0	240.0	19.00	18.00	503.0
9/19/2001	CT C	50	56.6	0.251	7.57	296.0	765.0	5.00	0.70	891.0
6/8/2001	CT 8	170,000	87.0	not taken	9.40	170.0	390.0	8.00	4.00	418.0
	Min	**1**	**22**	**0.25**	**5.34**	**100**	**200**	**0.05**	**0.05**	**96**
	Max	**16,000,000**	**2,880**	**1.09**	**9.80**	**4,230**	**5,650**	**70.00**	**50.00**	**4,220**
	GeoMean	**2,189**	**67**	**0.72**	**7.69**	**282**	**527**	**1.82**	**0.49**	**420**

Table C10: 2001 Large Ships Galley, Fish and Butcher Shop Collecting tanks.

Sample Date	Sample Name	Fecal Coliform MPN/100 ml	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	2	0.1	0.016	0.1	1.0	3.7	0.1	0.1	1.0
06/06/01	CT (butcher)	16000000	804.0	Not taken	7.10	941.0	3,320.0	0.05	0.05	427.0
08/21/01	CT (butcher)	80000	148.0	9.270	6.50	530.0	1,030.0	3.50	0.10	692.0
07/26/01	CT I (butcher)	1	141.0	1.350	7.00	311.0	712.0	100.00	0.05	2,360.0
08/02/01	CT9 (butcher)	1	29.6	0.574	7.40	89.9	240.0	4.00	0.50	915.0
06/12/01	HT (butcher)	Missing	130.0	Not taken	7.50	720.0	1,500.0	4.00	0.05	1,160.0
09/19/01	CT (butcher)	Missing	393.0	0.854	6.93	669.0	1,410.0	35.00	35.00	3,300.0
08/21/01	CT (galley)	230000	230.0	0.999	9.89	846.0	1,150.0	3.50	0.10	427.0
06/27/01	HT 14PT (galley)	1600000	700.0	Not taken	4.80	2,200.0	3,500.0	0.05	0.05	1,090.0
06/27/01	HT 3C (galley)	Missing	860.0	Not taken	4.70	1,700.0	2,700.0	0.05	0.05	672.0
05/24/01	CT H – (galley)	5000	2300.0	Not taken	4.10	5,900.0	6,400.0	0.05	0.05	1,200.0
06/06/01	CT (galley)	7000	492.0	Not taken	9.40	1,460.0	2,360.0	0.40	0.20	665.0
09/19/01	CT (galley)	23	266.0	0.245	10.20	599.0	642.0	10.00	3.40	878.0
06/01/01	CT (galley)	Missing	780.0	Not taken	9.60	1,600.0	2,300.0	3.50	0.05	665.0
05/25/01	CT 8 (galley)	50	880.0	Not taken	7.60	1,600.0	1,700.0	2.80	1.30	1,100.0
07/26/01	CT H (galley)	170000	2520.0	0.859	4.80	not found	3,700.0	not found	not found	not found
09/25/01	CT (galley)	30	173.0	2.190	6.62	239.0	536.0	2.80	0.20	260.0
06/05/01	CT (galley)	1	130.0	Not taken	9.30	760.0	1,400.0	30.00	1.00	1,180.0
07/26/01	CT L (fish prep)	1	238.0	7.410	6.80	663.0	1,290.0	50.00	7.00	1,710.0
06/12/01	HT (fish shop)	1	170.0	Not taken	8.20	550.0	1,100.0	4.00	1.50	1,150.0
09/19/01	CT (fish shop)	1	163.0	3.290	6.95	414.0	914.0	35.00	10.00	1,640.0
08/02/01	CT 10 (fish prep)	624	124.0	0.210	7.10	82.6	308.0	3.00	3.50	267.0
06/08/01	CT (fish shop)	1	580.0	Not taken	7.00	1,000.0	1,900.0	2.00	0.10	1,850.0

Sample Date	Sample Name	Fecal Coliform MPN/100 ml	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
06/06/01	CT (fish shop)	500000	1610.0	Not taken	7.00	1,470.0	2,670.0	0.05	0.05	563.0
	Min	**1**	**30**	**0.21**	**4.10**	**83**	**240**	**0.05**	**0.05**	**260**
	Max	**16,000,000**	**2,520**	**9.27**	**10.20**	**5,900**	**6,400**	**100**	**35**	**3,300**
	GeoMean	**402**	**349**	**1.27**	**7.04**	**728**	**1,414**	**2**	**0.34**	**904**

Table C11: 2001 Large Ships Galley Stored in Ballast Tanks, Held until the Ship is 1 Mile from Shore and Traveling a Minimum 6 Knots.

Sample Date	Sample Name	Fecal Coliform (MPN/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
05/31/01	DB8 (galley)	Invalidated	270.0	not taken	4.00	1,300.0	2,700.0	0.05	0.05	1,300.0
07/23/01	DB 8 (galley)	Invalidated	383.0	0.008	4.10	1,150.0	1,290.0	0.05	0.05	2,870.0
07/26/01	DB T and #8,11,13 domestic/galley	230,000	46.2	0.650	7.60	not found	521.0	not found	not found	521.0
06/21/01	DB 15P (galley)	Invalidated	430.0	Not taken	6.20	1,440.0	1,920.0	0.10	1.70	509.0
06/22/01	DB 15S (galley)	358,000	597.0	Not taken	4.40	1,520.0	2,270.0	0.10	2.00	757.0
08/02/01	DB 15P (galley)	Invalidated	368.0	0.884	5.10	980.0	1,550.0	3.30	3.00	885.0
08/02/01	DB 15S (galley)	15,300,000	Not found	Not taken	5.30	1,080.0	1,620.0	0.50	0.50	883.0
07/10/01	DB 11 (Galley)	Invalidated	149.0	0.008	not found	814.0	1,520.0	0.05	0.05	803.0
06/07/01	DB11 (Galley)	Invalidated	26000.0	Not taken	3.60	7,800.0	54,000.0	0.05	0.05	2,670.0
08/22/01	DB 11 (galley)	300,000	1390.0	1.380	4.05	2,900.0	3,950.0	0.05	0.05	863.0
	Min	**230,000**	**46**	**0.01**	**3.60**	**814**	**521**	**0.05**	**0.05**	**509**
	Max	**15,300,000**	**26,000**	**1.38**	**7.60**	**7,800**	**54,000**	**3.30**	**3.00**	**2,870**
	Geo Mean	**784,072**	**512**	**0.14**	**4.80**	**1,587**	**2,404**	**0.12**	**0.23**	**1,008**

Table C12: 2001 Large Ships Graywater Mixed Held in Ballast Tanks (Discharged 1 Mile from Shore Traveling a Minimum 6 Knots)

Sample Date	Sample Name	Fecal Coliform (MPN/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
08/20/01	DB 11	500,000	259.0	0.634	6.30	216	982	0.05	0.05	30,500
08/29/01	DB3C	1,700,000	365.0	0.008	4.77	936	174	0.05	0.05	691.0
08/29/01	DB7P	700,000	40.3	0.008	6.75	130	Not taken	0.05	0.05	296.0
08/29/01	DB7S	300,000	43.6	1.920	7.01	171	289	0.05	0.05	355.0
	Min	**300,000**	**40.3**	**0.01**	**4.77**	**130**	**174**	**0.05**	**0.05**	**296**
	Max	**1,700,000**	**365.0**	**1.92**	**7.01**	**936**	**982**	**0.05**	**0.05**	**30,500**
	GeoMean	**649,994**	**113.5**	**0.09**	**6.14**	**259**	**367**	**0.05**	**0.05**	**1,220**

Table C13: 2001 Large Ships Laundry Graywater in Ballast Tanks (Discharged 1 Mile from Shore Traveling a minimum 6 Knots)

Sample Date	Sample Name	Fecal Coliform (MPN/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	PH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
05/31/01	DB-Laundry)	Invalidated	23.0	not taken	9.90	120.0	410.0	0.20	0.10	350.0
07/26/01	DB (laundry)	2,400,000	18.0	0.394	6.90	75.0	268.0	0.20	0.05	153.0
06/21/01	DB 9 (laundry)	Invalidated	68.0	not taken	9.70	160.0	410.0	0.40	0.70	465.0
08/02/01	DB Laundry	48,000	43.0	0.399	9.20	164.0	502.0	1.20	1.00	300.0
07/10/01	DB (Laundry)	Invalidated	14.6	0.131	8.25	79.0	310.0	0.30	0.05	200.0
06/07/01	DB6 (Laundry)	Invalidated	400.0	not taken	4.20	1,400.0	2,600.0	0.05	0.05	3,360.0
08/22/01	DB 6 (laundry)	2,400,000	743.0	7.350	6.67	1,320.0	2,250.0	0.10	0.05	2,830.0
	Min	**48,000**	**15**	**0.13**	**4.20**	**75**	**268**	**0.05**	**0.05**	**153**
	Max	**2,400,000**	**743**	**7.35**	**9.90**	**1,400**	**2,600**	**1.20**	**1.00**	**3,360**
	GeoMean	**651,460**	**66**	**0.62**	**7.56**	**230**	**634**	**0.22**	**0.12**	**545**

Table C14: 2001 Large Ships Laundry Graywater Collected and Discharged Immediately

Sample Date	Sample Name	Fecal Coliform (MPN/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
06/27/01	HT 7PT (laundry)	30	24.0	not taken	9.20	150.0	340.0	2.00	2.00	647.0
06/27/01	HT 7SB (laundry)	30	20.0	not taken	7.60	49.0	960.0	0.05	0.05	9,740.0
	Min	**30**	**20**	**not taken**	**7.60**	**49**	**340**	**0.05**	**0.05**	**647**
	Max	**30**	**24**	**not taken**	**9.20**	**150**	**960**	**2.00**	**2.00**	**9,740**
	GeoMean	**30**	**22**	**not taken**	**8.36**	**86**	**571**	**0.32**	**0.32**	**2,510**

Table C15: 2001 Large Ships Mixed Graywater Held in Collecting Tanks and Immediately Discharged

Sample Date	Sample Name	Fecal Coliform (MPN/100 ml)*	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
	MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
06/06/01	CT B	2	21.0	not taken	7.80	86.6	155.0	0.80	0.50	271.0
06/06/01	CT C	70,000	4770.0	not taken	5.20	1,920.0	3,100.0	0.05	0.05	501.0
06/06/01	CT E	90	45.0	not taken	7.90	101.0	151.0	0.50	0.30	236.0
06/06/01	CT F	50,000	40.4	not taken	7.40	55.8	144.0	0.05	0.05	174.0
05/30/01	HT – 2102	1	260.0	not taken	9.80	110.0	540.0	3.00	0.60	3,970.0
05/30/01	HT – 9149	9,000,000	710.0	not taken	6.40	770.0	1,100.0	0.05	0.05	1,020.0
05/30/01	HT – 9249	9,000,000	370.0	not taken	6.50	510.0	690.0	0.05	0.05	1,310.0
08/17/01	HT – 2229	2,800,000	45.4	0.739	6.08	194.0	361.0	0.05	0.05	345.0
08/17/01	HT – 9149	3,500,000	144.0	0.301	6.25	325.0	722.0	0.05	0.05	1,710.0
08/17/01	HT – 9249	16,000,000	76.5	0.481	6.00	324.0	520.0	0.05	0.05	1,310.0
06/12/01	HT E	Invalidated	27.0	not taken	7.50	110.0	230.0	2.50	0.05	337.0
06/12/01	HT F	Invalidated	94.0	not taken	7.20	600.0	1,200.0	4.00	1.80	399.0
06/12/01	HT G	Invalidated	18.0	not taken	7.60	220.0	380.0	0.30	0.05	183.0
	Min	**1**	**18**	**0.301**	**5.20**	**55.80**	**144.00**	**0.05**	**0.05**	**174.00**
	Max	**16,000,000**	**4,770**	**0.739**	**9.80**	**1,920.00**	**3,100.00**	**4.00**	**1.80**	**3,970.00**
	GeoMean	**38,933**	**108**	**0.475**	**6.96**	**245.88**	**473.94**	**0.22**	**0.11**	**562.35**

Table C16: 2001 Large Ships Combining Blackwater and Graywater and Immediately Treating and Discharging

Treatment Type	Sample Date	Waste Type	Fecal Coliform (MPN/100 ml)	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
		MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
Advanced	05/14/01	Black/Gray	2	0.7	1.180	3.96	63.2	99.7	0.05	0.05	16.1
Advanced	07/31/01	Black/Gray	1	0.7	0.732	7.40	0.5	1.7	0.05	0.05	61.9
Advanced	08/08/01	Black/Gray	1	0.7	0.616	7.10	2.2	1.7	0.05	0.05	36.2
Advanced	08/08/01	Black/Gray	1	0.7	0.954	7.00	5.4	10.4	0.10	0.05	69.3
Advanced	08/09/01	Black/Gray	1	0.7	0.463	6.80	3.4	1.7	0.05	0.05	45.8
Advanced	08/10/01	Black/Gray	1	0.7	0.541	7.20	0.5	1.7	0.05	0.05	46.1
Advanced	08/10/01	Black/Gray	1	0.7	0.485	7.00	10.8	23.2	0.05	0.05	65.0
Advanced	08/11/01	Black/Gray	1	0.7	0.267	7.40	2.1	1.7	0.05	0.05	85.0
Advanced	08/11/01	Black/Gray	1	0.7	0.171	7.30	0.5	12.6	0.05	0.05	86.8
Advanced	09/09/01	Black/Gray	1	0.7	0.454	7.05	0.5	14.7	0.05	0.05	13.2
Advanced	06/28/01	Black/Gray	1	0.7	0.640	7.20	not found	not found	not found	not found	not found
Advanced	08/01/01	Black/Gray	1	0.7	17.900	7.55	0.5	1.7	0.05	0.05	570.0
Macerator/Chlorinator	07/13/01	Black/Gray	60	189.0	0.340	7.00	134.0	1,100.0	5.00	1.40	40,400.0
Macerator/Chlorinator	07/13/01	Black/Gray	5	128.0	3.490	7.10	190.0	973.0	2.50	0.40	34,400.0
Macerator/Chlorinator	08/08/01	Black/Gray	Invalidated	326.0	11.200	not found	313.0	not found	0.05	0.05	not found
Macerator/Chlorinator	08/08/01	Black/Gray	Invalidated	173.0	16.700	7.20	180.0	1,100.0	0.05	0.05	28,500.0
		Min	**1**	**0.7**	**0.171**	**3.96**	**0.50**	**1.7**	**0.05**	**0.05**	**13.2**
		Median	**1**	**0.7**	**0.628**	**7.10**	**3.44**	**11.5**	**0.05**	**0.05**	**67.2**
		Max	**60**	**326.0**	**17.900**	**7.55**	**313.00**	**1,100.0**	**5.00**	**1.40**	**40,400.0**

Treatment Type	Sample Date	Waste Type	Fecal Coliform (MPN/100 ml)	TSS (mg/l)	Ammonia (mg/l)	pH	BOD (mg/l)	COD (mg/l)	Cl, Residual (mg/l)	Cl, Free (mg/l)	Conductivity (umhos/cm)
		MDL	**2**	**0.1**	**0.016**	**0.1**	**1.0**	**3.7**	**0.1**	**0.1**	**1.0**
		Geometric Mean	**2**	**2.7**	**1.076**	**6.88**	**6.73**	**16.7**	**0.09**	**0.07**	**223.0**

Table C17: 2001 Large Ship Priority Pollutants/Chlorinated Organics All Graywater Categories

Sample Name	Water type	Sample Date	Chloroethane	Carbon Tetrachloride	Chloroform	1,1-Dichloro Propane	Tetrachloroethene	Trichloroethene
		MDL	**0.36**	**0.17**	**0.25**	**0.19**	**0.12**	**0.26**
CT	Accomo	19-Sep-01	7.9	0.085	170	0.095	0.06	0.13
CT	Galley	19-Sep-01	0.18	0.085	0.125	0.095	0.06	0.13
CT	Mixed Gray	17-Aug-01	0.18	0.085	19	0.095	35	5.1
CT	Mixed Gray	17-Aug-01	0.18	0.085	19	0.095	40	9
DB	Mixed Gray	29-Aug-01	0.18	0.085	12	0.095	0.7	0.13
DB	Mixed Gray	29-Aug-01	0.18	0.085	8.9	0.095	0.78	0.13
DB	Mixed Gray	29-Aug-01	0.18	0.085	0.125	0.095	0.06	0.13
DB	Mixed Gray	29-Aug-01	0.18	0.085	0.125	0.095	0.06	0.13
DB	Galley	02-Aug-01	0.18	1.9	140	1.3	0.06	0.13
DB	Galley	22-Aug-01	0.18	0.085	37	0.095	0.06	0.13
DB	Galley	23-Jul-01	0.18	0.085	16	0.095	0.06	0.13
DB	Acc/galley	26-Jul-01	0.18	0.085	95	0.095	0.06	0.13
DB	Laundry	26-Jul-01	0.18	0.085	31	0.095	0.96	0.13
DB	Accomo	23-Jul-01	0.18	0.085	58	0.095	0.06	0.13
DB	Accomo	02-Aug-01	16	3.5	0.125	0.095	0.06	0.13
		Min	**0.18**	**0.085**	**0.125**	**0.095**	**0.06**	**0.13**
		Max	**16**	**3.5**	**170**	**1.3**	**40**	**9**
		GeoMean	**0.312**	**0.134**	**7.769**	**0.113**	**0.238**	**0.220**

Table C18: 2001 Large Ship Priority Pollutants/Chlorinated Phenols and Halomethanes
All graywater categories. All units in ug/l or parts per billion (ppb).

Tank Type	Water type	Sample Date	2,4-dichlorophenol	2,4,6-trichlorophenol	bromoform	dibromochloromethane	bromodichloromethane	methyl chloride	methylene chloride
		MDL	**0.53**	**0.39**	**0.32**	**0.32**	**0.23**	**1.2**	**1.2**
CT	Accomo	19-Sep-01	2.2	0.195	0.16	0.16	2.5	8.4	0.6
CT	Galley	19-Sep-01	42	40	0.16	0.16	6	0.6	0.6
CT	Mixed Gray	17-Aug-01	0.275	0.195	0.16	2.1	3	0.6	0.6
CT	Mixed Gray	17-Aug-01	0.275	0.195	1.4	2.4	3.4	0.6	0.6
DB	Mixed Gray	29-Aug-01	0.275	0.195	6.3	3.4	2.7	0.6	1.8
DB	Mixed Gray	29-Aug-01	0.275	0.195	6.5	3.5	3.1	0.6	1.9
DB	Mixed Gray	29-Aug-01	0.275	0.195	0.16	0.16	0.115	0.6	0.6
DB	Mixed Gray	29-Aug-01	0.275	0.195	0.16	0.16	0.115	0.6	0.6
DB	Galley	02-Aug-01	0.275	0.195	0.16	0.16	1.6	5	8.2
DB	Galley	22-Aug-01	0.275	0.195	0.16	0.16	1.3	0.6	0.6
DB	Galley	23-Jul-01	0.275	0.195	31	1.2	0.115	0.6	0.6
DB	Acc/galley	26-Jul-01	0.275	0.195	0.16	0.16	3.4	0.6	0.6
DB	Laundry	26-Jul-01	0.275	0.195	0.16	0.16	1.4	0.6	0.6
DB	Accomo	23-Jul-01	0.275	0.195	3	0.16	1.6	0.6	0.6
DB	Accomo	02-Aug-01	3.2	5.6	0.16	0.16	0.115	81	12
		Min	**0.275**	**0.195**	**0.16**	**0.16**	**0.115**	**0.6**	**0.6**
		Max	**42**	**40**	**31**	**3.5**	**6**	**81**	**12**
		GeoMean	**0.520**	**0.348**	**0.522**	**0.392**	**1.088**	**1.143**	**1.013**

Table C19: 2001 Large Ships Total Recoverable Metals. All Categories of Graywater.
All units in ug/l or parts per billion (ppb).

Tank Type	Water type	Sample Date	antimony	arsenic III	berylium	cadmium (TR)	chromium (TR)	copper (TR)	lead (TR)	nickel (TR)	selenium (TR)	silver (TR)	zinc (TR)
		MDL	**1.5**	**3.6**	**0.2**	**0.81**	**2.3**	**1.2**	**1.4**	**1.1**	**4.8**	**0.93**	**2.8**
CT	Accomo	19-Sep-01	0.75	1.44	0.1	0.0724	2.72	255	4.47	27.9	0.965	0.367	458
CT	Galley	19-Sep-01	0.75	0.434	0.1	0.4	10.6	74.9	2.51	15.4	0.862	1.43	173
CT	Mixed Gray	17-Aug-01	2.74	3.52	0.0867	0.789	4.11	275	78.6	51.9	9.14	0.43	10300
CT	Mixed Gray	17-Aug-01	0.417	2.55	0.0167	0.4	4.88	272	12.6	56	6.63	0.167	1390
DB	Mixed Gray	29-Aug-01	0.75	0.18	0.1	0.4	1.15	0.6	0.7	0.55	2.4	0.45	1.4
DB	Mixed Gray	29-Aug-01	0.75	0.18	0.1	0.4	1.15	0.6	0.7	0.55	2.4	0.45	1.4
DB	Mixed Gray	29-Aug-01	1.01	0.419	0.0157	0.317	1.82	338	1.7	15	0.566	0.231	289
DB	Mixed Gray	29-Aug-01	0.893	0.447	0.0274	0.26	3.1	267	2.25	13.7	0.771	0.138	228
DB	Galley	02-Aug-01	0.125	0.846	0.0289	0.177	10.7	652	1.06	17.1	1.16	0.294	106
DB	Galley	22-Aug-01	0.365	2.38	0.0206	0.108	8.76	69.3	2.73	13.2	1.25	1.18	206
DB	Galley	23-Jul-01	0.748	8.27	0.1	0.4	13.6	1710	94.7	32.3	31.5	1.68	400
DB	Acc/galley	26-Jul-01	0.364	0.454	0.0273	0.111	3.87	170	5.7	16.9	1.28	0.15	411
DB	Laundry	26-Jul-01	0.635	0.192	0.1	0.308	2.05	44.1	3.27	5.25	0.396	0.384	163
DB	Accomo	23-Jul-01	0.434	2.43	0.1	0.4	4.96	174	4.25	10.7	8.99	0.901	270
DB	Accomo	02-Aug-01	0.338	0.559	0.1	0.281	2.62	355	2.75	8.71	1.76	0.431	276

Tank Type	Water type	Sample Date	antimony	arsenic III	berylium	cadmium (TR)	chromium (TR)	copper (TR)	lead (TR)	nickel (TR)	selenium (TR)	silver (TR)	zinc (TR)
		MDL	1.5	3.6	0.2	0.81	2.3	1.2	1.4	1.1	4.8	0.93	2.8
		Min	0.125	0.18	0.0157	0.0724	1.15	0.6	0.7	0.55	0.396	0.138	1.4
		Max	2.74	8.27	0.1	0.789	13.6	1710	94.7	56	31.5	1.68	10300
		GeoMean	0.591	0.835	0.054	0.273	3.833	103.439	4.039	11.084	2.047	0.430	179.346

Table C20: 2001 Large Ship Priority Pollutants. All Categories of Graywater Non-chlorinated Phenols and Phthalate Esters
All units in ug/l or parts per billion (ppb).

Tank Type	Water Type	Sample Date	Acrylonitrile	Ethyl Benzene	Toluene	Phenol	Bis(2-Ethylhexyl)Phthalate	Butylbenzylphthalate	Diethylphthalate	Di-N-Butylphthalate	Di-N-Octylphthalate
		MDL	**0.33**	**0.19**	**0.25**	**0.88**	**0.69**	**0.38**	**0.55**	**1.4**	**0.33**
CT	Accomo	19-Sep-01	0.165	0.095	0.125	0.44	8.2	0.19	9.4	0.7	0.125
CT	Galley	19-Sep-01	4	0.095	0.125	0.44	9.1	1.4	6.9	1.7	0.125
CT	Mixed Gray	17-Aug-01	0.165	0.095	0.125	0.44	55	0.19	7.9	2.9	3.5
CT	Mixed Gray	17-Aug-01	0.165	0.095	0.125	0.44	15	0.19	7.4	3.8	0.125
DB	Mixed Gray	29-Aug-01	0.165	0.52	1.1	4	15	0.19	17	0.7	0.125
DB	Mixed Gray	29-Aug-01	0.165	0.51	0.125	0.44	21	0.19	20	0.7	0.125
DB	Mixed Gray	29-Aug-01	0.165	0.095	0.125	0.44	0.35	0.19	0.275	0.7	0.125
DB	Mixed Gray	29-Aug-01	0.165	0.095	0.125	0.44	0.35	0.19	0.275	0.7	0.125
DB	Galley	02-Aug-01	0.165	0.095	2.2	0.44	3.4	0.19	7.6	2.2	0.125
DB	Galley	22-Aug-01	0.165	0.095	0.125	0.44	3.1	2.7	3.6	2.7	0.125
DB	Galley	23-Jul-01	0.165	0.51	1.7	1.8	5.8	1.9	6.3	2.9	0.125
DB	Acc/galley	26-Jul-01	0.165	58	0.125	0.44	14	0.19	12	14	0.125
DB	Laundry	26-Jul-01	0.165	1.8	0.125	0.44	17	0.19	15	4	0.125
DB	Accomo	23-Jul-01	0.165	0.095	0.83	0.44	8.9	2.3	9.6	1.9	0.125
DB	Accomo	02-Aug-01	0.165	0.095	0.125	0.44	5.2	0.19	13	3.7	0.125
		Min	**0.165**	**0.095**	**0.125**	**0.44**	**0.35**	**0.19**	**0.275**	**0.7**	**0.125**
		Max	**4**	**58**	**2.2**	**4**	**55**	**2.7**	**20**	**14**	**3.5**
		GeoMean	**0.204**	**0.248**	**0.236**	**0.560**	**6.510**	**0.357**	**5.913**	**1.944**	**0.156**

Table C21: 2001 Large Ship Conventional Pollutants taken during Priority Pollutant Sampling. All Graywater Categories.

Tank Type	Water type	Sample Date	Ammonia mg/l	PH	BOD5 mg/l	COD mg/l	TSS mg/l	total CL mg/l	Fecal coliform MPU/100 ml	Conductivity Umhos/cm	Free CL mg/l	Oil & grease mg/l	TOC mg/l	Alkalinity mg/l as CaCO3	total N mg/l	phosphorus mg/l	TKN mg/l	Settable Solids mg/l
		MDL	**0.016**	**0.1**	**1**	**3.4**	**1.3**	**0.1**	**2**	**1**	**0.1**	**1**	**0.3**	**0.019**	**0.019**	**0.22**	**0.1**	**0.1**
CT	Accomo	19-Sep-01	0.251	7.57	296	765	56.6	5	50	891	0.7	0.5	529	193	0.59	42.1	11.1	0.11
CT	Galley	19-Sep-01	0.245	10.2	599	642	266	10	23	878	3.4	0.5	304	242	0.72	15.2	11.1	0.72
CT	Mixed Gray	17-Aug-01	0.301	6.25	325	722	144	0.05	3500000	1710	0.05	130	885	65.5	0.0095	5.4	12.9	2.8
CT	Mixed Gray	17-Aug-01	0.481	6	324	520	76.5	0.05	16000000	1310	0.05	98	454	62.7	0.0095	4.17	18.5	1.4
DB	Mixed Gray	29-Aug-01	Na	Na	Na	Na	Na	Na	Na	Na	Na	46	Na	Na	Na	Na	Na	Na
DB	Mixed Gray	29-Aug-01	Na	Na	Na	Na	Na	Na	Na	Na	Na	38	Na	Na	Na	Na	Na	Na
DB	Mixed Gray	29-Aug-01	Na	6.75	130	Na	40.3	0.05	700000	296	0.05	Na	305	35.8	Na	1.04	3.7	0.05
DB	Mixed Gray	29-Aug-01	1.92	7.01	171	289	43.6	0.05	300000	355	0.05	Na	279	67.2	0.0095	2.76	9.1	0.05
DB	Galley	02-Aug-01	Na	5.3	1080	1620	Na	0.5	15300000	883	0.5	290	480	33	0.0095	7.96	22.2	0.73
DB	Galley	22-Aug-01	1.38	4.05	2900	3950	1390	0.05	300000	863	0.05	200	1570	Na	Na	19	61.1	35
DB	Galley	23-Jul-01	Na	4.1	1150	1290	383	0.05	invalid	2870	0.05	Na	336	0.095	0.0095	6.1	50	1.3
DB	Acc/galley	26-Jul-01	0.65	7.6	Na	521	46.2	Na	230000	521	Na	Na	137	50.2	0.0095	3.49	Na	0.21
DB	Laundry	26-Jul-01	0.394	6.9	75	268	18	0.2	2400000	153	0.05	Na	65	28.2	0.0095	5.54	5.6	0.1

Tank Type	Water type	Sample Date	Ammonia mg/l	PH	BOD5 mg/l	COD mg/l	TSS mg/l	total CL mg/l	Fecal coliform MPU/100 ml	Conductivity Umhos/cm	Free CL mg/l	Oil & grease mg/l	TOC mg/l	Alkalinity mg/l as CaCO3	total N mg/l	phosphorus mg/l	TKN mg/l	Settable Solids mg/l
		MDL	**0.016**	**0.1**	**1**	**3.4**	**1.3**	**0.1**	**2**	**1**	**0.1**	**1**	**0.3**	**0.019**	**0.019**	**0.22**	**0.1**	**0.1**
DB	Accomo	23-Jul-01	Na	5.2	373	765	102	0.05	invalid	2060	0.05	Na	231	56.5	0.0095	5.89	20.9	0.11
DB	Accomo	02-Aug-01	Na	7.7	151	295	31	3.5	Invalid	953	0.7	47	87	82	0.0095	2.18	7.5	0.05
		Min	**0.016**	**0.1**	**1**	**3.4**	**1.3**	**0.05**	**2**	**1**	**0.05**	**0.5**	**0.3**	**0.019**	**0.0095**	**0.22**	**0.1**	**0.05**
		Max	**1.92**	**10.2**	**2900**	**3950**	**1390**	**10**	**16000000**	**2870**	**3.4**	**290**	**1570**	**242**	**0.72**	**42.1**	**61.1**	**35**
		GeoMean	**0.528**	**6.31**	**368.72**	**700.08**	**92.800**	**0.221**	**179261**	**808.452**	**0.134**	**29.146**	**310.482**	**38.145**	**0.020**	**5.854**	**14.05**	**0.376**

Table C22: 2001 Large Ships Priority Pollutants for Blackwater Chlorinated Benzenes and Halomethanes
All units in ug/l or parts per billion (ppb).

Type	Water type	Sample Date	1,4 Chlorobenzene	Chloroform	Tetrachloro ethene	Trichloro ethene	Bromoform	Dibromochloro methane	Bromodichlor omethane	Antimony(Tr)
			0.36	**0.19**	**0.26**	**0.53**	**0.32**	**0.23**	**1.2**	**3.6**
Advanced	Mixed BW&GW	20-Sep-01	0.18	4.2	11	0.51	0.16	0.115	0.68	1.8
Advanced	Mixed BW&GW	09-Sep-01	0.18	11	0.13	0.25	0.16	0.115	0.6	0.104
Macerator	Mixed BW&GW	08-Aug-01	3.9	22	0.13	0.25	26	9.6	4.8	1.8
Macerator	Mixed BW&GW	08-Aug-01	0.18	27	0.13	0.25	13	3.3	0.6	1.8
No treatment/ DB	Mixed BW&GW	19-Aug-01	0.18	1.7	0.13	0.25	0.16	0.115	0.6	22.7
Biological	BW	19-Aug-01	0.18	0.87	0.13	0.25	0.16	0.115	0.6	1.99
		Min	**0.18**	**0.87**	**0.13**	**0.25**	**0.16**	**0.115**	**0.6**	**0.104**
		Max	**3.9**	**27**	**11**	**0.51**	**26**	**9.6**	**4.8**	**22.7**
		GeoMean	**0.301**	**5.862**	**0.272**	**0.282**	**0.778**	**0.421**	**0.866**	**1.736**

Table C23: 2001 Large Ships Blackwater Priority Pollutants Total Recoverable Metals

All units in ug/l or parts per billion (ppb).

Type	Water type	Sample Date	Arsenic III	Berylium	Cadmium (TR)	Chromium (TR)	Copper (TR)	Lead (TR)	Nickel (TR)	Selenium (TR)	Silver (TR)	Zinc (TR)
		MDL	**0.2**	**0.81**	**2.3**	**1.2**	**1.4**	**1.1**	**4.8**	**0.93**	**2.8**	**0.33**
Advanced	Mixed BW&GW	20-Sep-01	1.09	0.4	1.15	0.685	2.66	0.0628	18.3	1.05	1.4	32.4
Advanced	Mixed BW&GW	09-Sep-01	0.1	0.4	1.15	0.196	0.501	0.195	0.688	0.213	1.4	3.02
Macerator	Mixed BW&GW	08-Aug-01	32.8	0.465	1.15	8.12	203	3.67	25.4	105	1.4	228
Macerator	Mixed BW&GW	08-Aug-01	36	0.4	1.15	6.92	98.7	0.55	22.7	155	1.4	111
No treatment/DB	Mixed BW&GW	19-Aug-01	53.4	0.381	1.15	0.6	169	3.43	16.2	152	1.66	268
Biological	BW	19-Aug-01	9.03	0.4	2.52	2.61	1670	80.3	38.1	8.31	0.983	3020
		Min	**0.1**	**0.381**	**1.15**	**0.196**	**0.501**	**0.0628**	**0.688**	**0.213**	**0.983**	**3.02**
		Max	**53.4**	**0.465**	**2.52**	**8.12**	**1670**	**80.3**	**38.1**	**155**	**1.66**	**3020**
		GeoMean	**6.292**	**0.407**	**1.311**	**1.509**	**44.278**	**1.377**	**12.840**	**12.895**	**1.358**	**112.286**

Table C24: 2001 Large Ships Blackwater Priority Pollutants (Phtalate Esters)

All units in ug/l or parts per billion (ppb).

Type	Water Type	Sample Date	Ethylbenzene	Phenol	Bis(2-Ethylhexyl)Phthalate	Butylbenzylphthalate	Diethylphthalate	Di-N-Butylphthalate
		MDL	**0.25**	**0.69**	**0.38**	**0.55**	**1.4**	**0.33**
Advanced	Mixed BW&GW	20-Sep-01	0.125	0.35	0.19	0.275	0.7	3.2
Advanced	Mixed BW&GW	09-Sep-01	0.125	0.35	4.2	0.275	0.7	0.165
Macerator	Mixed BW&GW	08-Aug-01	0.125	0.35	0.19	0.275	0.7	0.165
Macerator	Mixed BW&GW	08-Aug-01	0.53	2.3	3.1	0.275	2.3	2.9
No treatment/DB	Mixed BW&GW	19-Aug-01	0.125	0.35	7	1.2	0.7	3.7
Biological	BW	19-Aug-01	0.125	0.35	0.19	0.275	0.7	1.8
		Min	**0.125**	**0.35**	**0.19**	**0.275**	**0.7**	**0.165**
		Max	**0.53**	**2.3**	**7**	**1.2**	**2.3**	**3.7**
		GeoMean	**0.159**	**0.479**	**0.925**	**0.352**	**0.853**	**1.091**

Table C25: 2001 Large Ships Blackwater Conventional Pollutants Sampled With Priority Pollutants

Type	Water type	Sample Date Units	Ammonia mg/l	pH	BOD5 mg/l	COD mg/l	TSS mg/l	Total CL mg/l	Fecal Coliform MPU/ 100ml	Conductivity Umhos/cm	Free CL mg/l	Oil & Grease mg/l	TOC mg/l	Alkalinity mg/l as CaCO3	Total N mg/l	Phosphorus mg/l	TKN mg/l	Settable Solids mg/l
		MDL	**0.1**	**1**	**3.4**	**1.3**	**0.1**	**2**	**1**	**0.1**	**1**	**0.3**	**0.019**	**0.019**	**0.22**	**0.1**	**0.1**	**0.12**
Advanced	Mixed BW& GW	20-Sep-01	17.9	7.55	1.7	0.65	0.05	0.05	1	570	0.05	n/a	12	99.7	1.93	14.3	19.4	0.05
Advanced	Mixed BW& GW	09-Sep-01	0.454	7.05	1.7	14.7	n/a	n/a	n/a	13.2	n/a	0.05	1	6.25	0.11	0.05	11.1	0.05
Macerator	Mixed BW& GW	08-Aug-01	11.2	7.1	313	1180	326	0.05	n/a	26400	0.05	n/a	229	n/a	0.59	n/a	29.6	10
Macerator	Mixed BW& GW	08-Aug-01	16.7	7.2	180	1100	173	0.05	n/a	28500	0.05	35	100	151	0.46	3.79	27.8	4.5
No treatment/ DB	Mixed BW& GW	19-Aug-01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Biological	BW	19-Aug-01	292	7.85	258	1630	692	0.05	1700000	3590	0.05	0.15	373	743	41.2	102	363	32
		Min	**0.454**	**7.05**	**1.7**	**0.65**	**0.05**	**0.05**	**1**	**13.2**	**0.05**	**0.05**	**1**	**6.25**	**0.11**	**0.05**	**11.1**	**0.05**
		Max	**292**	**7.85**	**313**	**1630**	**692**	**0.05**	**1700000**	**28500**	**0.05**	**35**	**373**	**743**	**41.2**	**102**	**363**	**32**
		GeoMean	**13.472**	**7.34**	**33.471**	**115.12**	**37.375**	**0.050**	**1303.84**	**1826.411**	**0.050**	**0.640**	**40.008**	**91.440**	**1.189**	**4.077**	**36.5**	**1.292**

Table C26: 2000 Priority Pollutants for Graywater.

All units in ug/l or part per billion (ppb)

Sample Name	1,4 Dichloro benzene	Chloro ethane	1,2-Dichloro ethane	1,1,2,2,-Tetra chloroethane	Bis(2-Chloro ethoxy) Methane	Carbon tetra chloride	Chloroform	Tetrachloro ethene	Trichloro ethene	2,4,6-Trichloro phenol	Bromoform	Dibromo chloro methane	Bromodichlor omethane	Methyl chloride
MDL	**0.28**	**0.36**	**0.37**	**0.22**	**0.39**	**0.17**	**0.25**	**0.12**	**0.26**	**0.50**	**0.32**	**0.32**	**0.23**	**1.2**
Ballast tank 5S			0.75				15	230	71				1.1	
Composite graywater										2.3				
Composite# 4,6,11														
Gray water accumulation tank 4							4				2.1	2.8	2	
Gray water composite (galley,accumulation,laundry)					14									
Gray water galley tank 4							2				1.2	1.3	0.98	
Gray water overboard			0.52				1.8							
Graywater composite														
Graywater port							15							
Graywater starboard							19				1.1			
Gry 78 port							44						1.3	
Gry accom			0.7	0.91		1.8	313	11.65	0.67		41.2	27.1	29.52	28.3
Gry ballast #6							4.1	0.74				1.4	1.5	
Gry comp	11													
Gry composite	2.2													
Gry gal/acco							19						1	
Gry galley				1			292.8	2.2					2.58	
Gry galley #11							1.4				1.9			
Gry galley tank #11		1.5					48				9.8	14	16	3
Gry galley tank H			0.76				14							
Gry HTS composite														
Gry laundry							207	954	8.2				0.57	
Gry pump accom.							2.3							
Gry tank #2			0.65				1.8	7.7	1.6					
Gry tank 3C							26						0.51	

Sample Name	1,4 Dichloro benzene	Chloro ethane	1,2-Dichloro ethane	1,1,2,2,-Tetra chloroethane	Bis(2-Chloro ethoxy) Methane	Carbon tetra chloride	Chloroform	Tetrachloro ethene	Trichloro ethene	2,4,6-Trichloro phenol	Bromoform	Dibromo chloro methane	Bromodichlor omethane	Methyl chloride
MDL	**0.28**	**0.36**	**0.37**	**0.22**	**0.39**	**0.17**	**0.25**	**0.12**	**0.26**	**0.50**	**0.32**	**0.32**	**0.23**	**1.2**
Gry tank 7 port and starboard							16				1.2	1.1	2	
Gry tank C							15					0.86	2.1	
Gry Tank F							6.5	4.2			0.54	4.2	1.1	
Grywtr 5 tank (composite)										0.61				
Grywtr laundry room							13	2.3	0.76					
Grywtr shaft tank							34							23
Grywtr stabilizer port tank							25						0.69	
Main graywater			0.91				15				1.3	0.65	0.7	
Starboard graywater							96	0.46			32	64	89	

Table C27: 2000 Priority Pollutants for Graywater

All units in ug/l or part per billion (ppb) except for CYANIDE

Sample Name	Methylene chloride	Cadmiuim (TR)	Chromium (TR)	Copper (TR)	Cyanide (total) mg/L	Lead (TR)	Mercury (TR)	Nickel (TR)	Silver (TR)	Zinc(TR)
MDL	**1.2**	**0.027**	**0.076**	**0.040**	**0.0016**	**0.047**	**0.050**	**0.18**	**0.031**	**0.094**
Ballast tank 5S				150				46		460
Composite graywater				260	22	7.5				560
Composite# 4,6,11				2200					1.5	860
Gray water accumulation tank 4										
Gray water composite (galley,accumulation,laundry)				230		21				480
Gray water galley tank 4										
Gray water overboard		0.29	4	62		2.5	0.33		0.3	350
Graywater composite		0.48	30	1203.4		21.4		99	7.5	770
Graywater starboard										
Gry 78 port				180	22				2.3	750
Gry accom	4.8									
Gry ballast #6	3.2									
Gry comp			14	4320		387	0.33	184	4.9	2860
Gry composite			57	710		28		676	4	1460
Gry DHTS composite				720				46		600
Gry gal/acco										
Gry galley	41									
Gry galley #11										
Gry galley tank #11			53	650		62				530
Gry galley tank H										
Gry HTS composite				830				44		400
Gry laundry	67									
Gry pump accom.	0.69									
Gry tank #2				130				85		340
Gry tank 3C		12		1500				140		540
Gry tank 7 port and starboard				150						740
Gry tank C										
Gry Tank F	1.1			210						330
Grywtr 5 tank (composite)		0.35		480		14			3.5	

Sample Name	Methylene chloride	Cadmiuim (TR)	Chromium (TR)	Copper (TR)	Cyanide (total) mg/L	Lead (TR)	Mercury (TR)	Nickel (TR)	Silver (TR)	Zinc(TR)
MDL	**1.2**	**0.027**	**0.076**	**0.040**	**0.0016**	**0.047**	**0.050**	**0.18**	**0.031**	**0.094**
Grywtr laundry room										
Grywtr shaft tank										
Grywtr stabilizer port tank										
Main graywater										
Starboard graywater										

Table C28: 2000 Priority Pollutants for Graywater

All units in ug/l or part per billion (ppb)

Sample Name	Ethylbenzene	Naphthalene	Toluene	Phenol	Heptachlor	Bis(2-Ethylhexyl) Phthalate	Butylbenzyl Phthalate	Diethyl Phthalate	Dimethyl Phthalate	Di-N-Butyl Phthalate	Acena Phthene	Fluoran Thene	Fluorene	Phenan Threne
MDL	**0.37**	**0.20**	**0.51**	**0.85**	**0.15**	**0.67**	**0.37**	**0.53**	**0.49**	**1.4**	**0.47**	**0.52**	**0.44**	**0.53**
Ballast tank 5S			0.77			17		3.7		2.5				
Composite graywater						10		3		1.1				
Composite# 4,6,11						11								
Gray water accommodation tank 4														
Gray water composite mixed								1.1		6.5				
Gray water galley tank 4														
Gray water overboard						32								
Graywater composite				2.9		15	1.6	5.8		8.4				
Graywater port	1.6		1.4											
Graywater starboard	2.6		1.7											
Gry 78 port	0.53		0.47			20	1.1	4.5		2.2				1.4
Gry accom			11.41											
Gry ballast #6	1.5		1.3											
Gry comp					0.082	183	1.2	13		8.1				
Gry composite				1.2		112	9.6	12.8		10.3				
Gry DHTS composite		3				35		6		5.3	7.7	1.2	4.1	3.1
Gry gal/acco														
Gry galley			1.3											
Gry galley #11	1.1							5.8						
Gry galley tank #11						3.7		6.3		3.3				
Gry galley tank H														
Gry HTS composite						51	1.1	8.5		6.8				
Gry laundry														
Gry pump accom.	2.8		1.7											
Gry tank #2						20		5.8		2.1				
Gry tank 3C	0.68					7.6		3.6		3.3				
Gry tank 7 port and starboard	0.68			3.1		14		11		3				
Gry tank C	0.59													
Gry Tank F						13		15	1.1	1.6				
Grywtr 5 tank (composite)				2.2		19	0.61	9.7						
Grywtr laundry room	24		1.7											
Grywtr shaft tank	1													

Sample Name	Ethylbenzene	Naphthalene	Toluene	Phenol	Heptachlor	Bis(2-Ethylhexyl) Phthalate	Butylbenzyl Phthalate	Diethyl Phthalate	Dimethyl Phthalate	Di-N-Butyl Phthalate	Acena Phthene	Fluoran Thene	Fluorene	Phenan Threne
MDL	**0.37**	**0.20**	**0.51**	**0.85**	**0.15**	**0.67**	**0.37**	**0.53**	**0.49**	**1.4**	**0.47**	**0.52**	**0.44**	**0.53**
Grywtr stabilizer port tank														
Main graywater														

Table C29: 2000 Large Ships Priority Pollutants for Blackwater (in alphabetical order)

All units in ug/l or parts per billion (ppb)

Type	Sample Date	1,1,2,2-Tetrachloroethane	1,2-Dichlorobenzene	1,2-Dichloroethane	1,3-Dichlorobenzene	1,4-Dichlorobenzene	2,4,6-Trichlorophenol	2-Nitrophenol	4-Nitrophenol	Alpha-Bhc	Bis(2-Ethylhexyl) Phthalate	Bromodichloromethane	Bromoform	Butylbenzylphthalate	Carbon Tetrachloride
		0.44	**0.42**	**0.74**	**0.44**	**0.57**	**0.38**	**0.56**	**0.15**	**0.00352**	**0.67**	**0.46**	**0.63**	**0.37**	**0.34**
	08-Sep-00					1.1					1.5			1.1	
	14-Sep-00			0.75							17	1.1			
	20-Sep-00										6.5	6.3	16		
	21-Sep-00					2.8	2				3.7				
HT	21-Sep-00										8.8	1.7	1.1		
MSD	11-Aug-00										1.9				
	15-Aug-00										2		3.3		
	18-Aug-00					1.2					1.9	1.9	1.2		
	22-Aug-00			1.5								18	95		
	25-Aug-00							5.4				1.1			
	06-Sep-00			0.97						0.14		18	28		
	13-Sep-00											77	170		4.2
	14-Sep-00			0.89							1.4	110	14		2
	15-Sep-00			0.97							2.3	43	6.1		
	18-Sep-00	5.9	390		380	350	3.2				6.2	180	440		5.8
	20-Sep-00			0.66							5.1	53	80		1.6
	22-Sep-00											190	25		27
	26-Sep-00								7.7		1.8				
	29-Aug-00			1.2							3.6	3.6	30		
RO	02-Sep-00			1.9							4.1				
	10-Sep-00				1.2						1.3				

Table C30: 2000 Large Ships Priority Pollutants for Blackwater (in alphabetical order)

All units in ug/l or parts per billion (ppb), except for TOTAL CYANIDE

Type	Sample Date	Cadmium (TR)	Carbon tetra chloride	Chloro Form	Chromium (TR)	Copper (TR)	cyanide (total) mg/l	delta-bhc	Dibromo Chloro methane	Diethyl phthalate	di-n-butyl phthalate	di-n-octyl phthalate	Endosulphan sulfate	Ethyl benzene	Lead (TR)
	MDL	**0.027**	**0.34**	**1.3**	**0.076**	**0.040**	**0.0016**	**0.004**	**0.21**	**0.53**	**1.4**	**0.32**	**0.00382**	**0.37**	**0.047**
DB	15-Aug-00				3.1										
	08-Sep-00			0.79		510		0.068							30
	14-Sep-00			15		150				3.7	2.5				
	20-Sep-00			6.7		530				2.7	3.9			0.87	
	21-Sep-00				10	3900			0.99		8.2				
HT	21-Sep-00			13		6400				3.3	2.1			0.92	16
MSD	11-Aug-00					360									
	15-Aug-00	0.43		2.9		210				2.7				0.93	
	18-Aug-00			1.6		50			1.4		4.8				
	22-Aug-00			21	18	560	25		40						23
	25-Aug-00	0.26		18	1.5	150	51								1.8
	06-Sep-00			20		530	19	0.073	18				0.035		27
	13-Sep-00		4.2	210		240	73		88						
	14-Sep-00		2	140		170			63		3.2				18
	15-Sep-00			200		760			16		2				
	18-Sep-00		5.8	380	14	7100	28		270		2.7	1.2		4.7	
	20-Sep-00		1.6	93	19	360	26		56		3.1				
	21-Sep-00			1.6	25	130					2.6				
	22-Sep-00		27	1500					88						
	26-Sep-00	0.24		3.7		54					2.1				

Type	Sample Date	Cadmium (TR)	Carbon tetra chloride	Chloro Form	Chromium (TR)	Copper (TR)	cyanide (total) mg/l	delta-bhc	Dibromo Chloro methane	Diethyl phthalate	di-n-butyl phthalate	di-n-octyl phthalate	Endosulphan sulfate	Ethyl benzene	Lead (TR)
	MDL	**0.027**	**0.34**	**1.3**	**0.076**	**0.040**	**0.0016**	**0.004**	**0.21**	**0.53**	**1.4**	**0.32**	**0.00382**	**0.37**	**0.047**
OB	11-Aug-00			1.2											
	29-Aug-00			15	52	740			13	1.6	9.8			0.53	50
RO	02-Sep-00			4.8											
	10-Sep-00			4.1							1.1				

Table C31: 2000 Large Ships Priority Pollutants for Blackwater (in alphabetical order)

Type	Sample Date	Mercury (TR)	Methyl bromide	Methyl chloride	Methylene chloride	Nickel (TR)	Phenan Threne	Phenol	Silver (TR)	Tetrachloro ethene	Toluene	Trichloro ethene	Zinc (TR)
		0.050	**1.2**	**1.2**	**2.3**	**0.036**	**0.53**	**0.85**	**0.031**	**0.23**	**0.51**	**0.51**	**0.094**
DB	08-Sep-00	0.93						250					1200
	14-Sep-00					46				230	0.77	71	460
	20-Sep-00				1	42				33	0.69	1.3	530
	21-Sep-00	0.3						160					390
HT	21-Sep-00	0.84						17	2.1				1800
MSD	11-Aug-00							13	0.76				170
	15-Aug-00						1.8	29	0.59				390
	18-Aug-00								0.27				210
	22-Aug-00			25									1100
	25-Aug-00					130			0.18				350
	06-Sep-00					41			1.9				1000
	13-Sep-00	0.67											580
	14-Sep-00			9.4					1.5				800
	15-Sep-00	0.24									0.73		
	18-Sep-00	0.26	7	160	42				2	7.6	2.2		610
	20-Sep-00	0.23			1.8	89							620
	21-Sep-00	0.37						100					700
	22-Sep-00			81									
	26-Sep-00			240									250
OB	29-Aug-00								1.9				140
RO	02-Sep-00										0.58		7
	10-Sep-00							2.1					

Table C32: Large Ships Conventional Pollutants Minimums

Sample Date	Sample From	Waste Type Units	Ammonia Mg/L	PH	BOD Mg/L	COD Mg/L	TSS Mg/L	T Cl Mg/L	FECAL MPN	CONDUCT Umhos/cm	FREE CL Mg/L
		MDL	**0.16**	**0.1**	**1.0**	**0.3**	**0.1**	**0.1**	**2**	**1.0**	**0.1**
2000	MSD	Treated BW	17.6	4.6	49	510	200	0.05	1	not taken	0.05
2000	Ballast tank	BW&GW	0.19	5	72	130	40	0.05	1	not taken	0.05
2000	Collecting tanks	GW mixed	0.12	3.8	40	170	37	0.05	30	not taken	0.05
2000	Collecting tanks	GW laundry	0.008	3	6.7	180	4	0.05	1	not taken	0.05
2000	Collecting tanks	GW laundry Accommodation	0.61	6.7	58	240	30	0.05	1	Not taken	0.05
2000	Collecting tanks	GW Galley	0.008	3.7	11	25	21	0.05	5	Not taken	0.05
2000	Collecting tanks	GW accommodation	0.88	7.8	210	1340	110	0.05	9	Not taken	0.05
2001	Ballast tanks	GW Accommodation	0.01	4.20	97	240	31	0.05	1	306	0.05
2001	Collecting tanks	GW Accommodation	0.25	5.34	22	100	200	0.05	1	96	0.05
2001	Collecting tanks	GW Galley	0.21	4.1	83	240	30	0.05	Not taken	260	0.05
2001	Ballast tank	GW Galley	0.01	3.6	814	521	46	0.05	230000	509	0.05
2001	Ballast tank	GW mixed	0.01	4.77	130	174	40.3	0.05	649,994	296	0.05
2001	Ballast tank	GW laundry	0.13	4.20	75	268	15	0.05	48000	153	0.05
2001	Collecting tank	GW laundry	Not taken	7.6	49	340	20	0.05	30	647	0.05
2001	Collecting tank	GW mixed	0.301	5.2	55.8	144	18	0.05	1	174	0.05
2001	Treatment	GW/BW mixed	0.171	3.96	0.50	1.7	0.7	0.05	1	12.2	0.05
		Geo Mean all	0.11	4.68	44.58	160.30	27.50	0.05	23.13	184	0.05
		Geo Mean Collecting	0.030	4.33	140.85	237.65	32.18	0.05	1483	290	0.05
		Geo Mean Ballast	0.13	4.99	38.35	187.70	30.40	0.05	3.77	230	0.05

Table C33: Large Ships Conventional Pollutants Maximums

Sample Date	Sample From	Waste Type Units	Ammonia Mg/L	pH	BOD Mg/L	COD Mg/L	TSS Mg/L	T Cl Mg/L	Fecal MPN/100ml	Conduct Umhos/cm	Free Cl Mg/L
		MDL	**0.16**	**0.1**	**1.0**	**0.3**	**0.1**	**0.1**	**2**	**1.0**	**0.1**
2000	MSD	Treated BW	730	8.7	320	1400	1480	9	1400000	not taken	3.33
2000	Ballast tanks	BW&GW	200	8.3	650	1030	380	1.3	16000000	not taken	0.75
2000	Collecting tanks	GW mixed	26.9	10.3	1120	15700	3000	1.2	16000000	not taken	3.5
2000	Collecting tanks	GW laundry	10	10.5	290	1310	420	1	8000	not taken	0.8
2000	Collecting tanks	GW laundry Accommodation	45	7.3	69	240	200	2.8	230	not taken	0.4
2000	Collecting tanks	GW galley	11	9.5	37030	69080	29400	4	9000000	not taken	4
2000	Collecting tanks	GW accommodation	49	9	500	1340	800	1.5	1200	not taken	0.05
2001	Ballast tanks	GW accommodation	0.83	7.70	1,000	2,300	240	14.00	16000000	4,320	14.00
2001	Collecting tanks	GW accommodation	1.09	9.80	4,230	5,650	2,880	70.00	16000000	4,220	50.00
2001	Collecting tanks	GW galley	9.27	10.20	5900	6400	2520	100	Not taken	3300	35
2001	Ballast tanks	GW galley	1.38	4.8	1587	2404	512	3.3	15300000	2870	3.0
2001	Ballast tanks	GW mixed	1.92	7.01	936	982	365	0.05	1700000	30,500	0.05
2001	Ballast tanks	GW laundry	7.35	9.9	1400	2600	743	1.20	2400000	3360	1.0
2001	Collecting tanks	GW laundry	Not taken	9.2	150	960	24	2.00	30	9740	2.00
2001	Collecting tanks	GW mixed	0.739	9.8	1920	3100	4770	4.00	16000000	3970	1.80
2001	Treatment tanks	GW/BW mixed	17.9	7.55	3.44	11.5	0.7	5	60	40400	1.4
		GeoMean	10.49	8.57	712.77	1793.99	547	3.28	271877	6712	1.78
		GeoMean Ballast	**11.54**	**7.55**	**869.64**	**1652.41**	**515**	**1.79**	**5308273**	**5970**	**1.32**
		GeoMean Collecting tank	**9.14**	**9.46**	**1129.09**	**3321.24**	**1194**	**4.70**	**83843**	**4817**	**2.24**

Appendix 7
Fecal Coliform Monitoring Data from 2000 and 2001

Bacteria data for black, gray and combined black and gray water for summer of 2000.

if < or >, then use the value df = dilution factor

if ND, then use 2

if *, then sample holding time exceeded, but used value anyway

bacteria concentrations after dilution

Ship	Water	Qualifier	Bacteria Data	after df of 50,000	after df of 500,000	after df of 5,000,000
A	gry	nd	2	0.00004	0.000004	0.0000004
A	gry		50000	1	0.1	0.01
A	blk		300	0.006	0.0006	0.00006
A	gry		32000000	640	64	6.4
A	gry	nd	2	0.00004	0.000004	0.0000004
A	gry		27000	0.54	0.054	0.0054
A	blk	nd	2	0.00004	0.000004	0.0000004
B	gry	*	3500000	70	7	0.7
B	gry		490000	9.8	0.98	0.098
B	gry		350000	7	0.7	0.07
B	blk		350	0.007	0.0007	0.00007
B	blk		3500000	70	7	0.7
B	blk		9200000	184	18.4	1.84
B	blk	nd	2	0.00004	0.000004	0.0000004
B	gry		3000	0.06	0.006	0.0006
B	gry		30	0.0006	0.00006	0.000006
B	gry		16000000	320	32	3.2
B	blk		230	0.0046	0.00046	0.000046
B	blk		230	0.0046	0.00046	0.000046
B	blk	nd	2	0.00004	0.000004	0.0000004
B	blk		12000	0.24	0.024	0.0024
C	gry		170000	3.4	0.34	0.034
C	blk		16000000	320	32	3.2
C	blk	>	24000000	480	48	4.8
C	blk		1700000	34	3.4	0.34

Ship	Water	Qualifier	Bacteria Data	after df of 50,000	after df of 500,000	after df of 5,000,000
C	blk		8	0.00016	0.000016	0.0000016
C	blk		7.3	0.000146	0.0000146	0.00000146
C	blk		8	0.00016	0.000016	0.0000016
C	gry	<	2	0.00004	0.000004	0.0000004
C	gry	<	2	0.00004	0.000004	0.0000004
C	gry	<	2	0.00004	0.000004	0.0000004
C	blk		23000	0.46	0.046	0.0046
C	blk		110000	2.2	0.22	0.022
C	blk		2400000	48	4.8	0.48
D	gry	>	16000000	320	32	3.2
D	gry		170000	3.4	0.34	0.034
D	gry		28000	0.56	0.056	0.0056
D	blk		5000000	100	10	1
D	blk		800000	16	1.6	0.16
D	gry	<	2	0.00004	0.000004	0.0000004
D	gry		170000	3.4	0.34	0.034
D	gry		50000	1	0.1	0.01
D	gry		170000	3.4	0.34	0.034
D	blk	*	300000	6	0.6	0.06
D	blk		16000000	320	32	3.2
D	blk		30000	0.6	0.06	0.006
D	blk		2	0.00004	0.000004	0.0000004
E	gry		1300000	26	2.6	0.26
E	gry		700	0.014	0.0014	0.00014
E	gry	>	24000000	480	48	4.8
E	gry		5000000	100	10	1
E	gry		280000	5.6	0.56	0.056
E	blk		1400000	28	2.8	0.28
E	blk		700000	14	1.4	0.14
F	gry		900000	18	1.8	0.18
F	gry		70000	1.4	0.14	0.014
F	blk	>	2	0.00004	0.000004	0.0000004
F	blk		2	0.00004	0.000004	0.0000004
F	blk		23	0.00046	0.000046	0.0000046
F	blk	<	2	0.00004	0.000004	0.0000004
F	blk	<	2	0.00004	0.000004	0.0000004
F	gry		7000	0.14	0.014	0.0014
F	blk/gry		50000	1	0.1	0.01
F	blk		50000	1	0.1	0.01
F	blk		700	0.014	0.0014	0.00014

Ship	Water	Qualifier	Bacteria Data	after df of 50,000	after df of 500,000	after df of 5,000,000
F	blk		30	0.0006	0.00006	0.000006
F	blk		2300	0.046	0.0046	0.00046
F	blk	<	2	0.00004	0.000004	0.0000004
G	blk/gry		35000	0.7	0.07	0.007
G	blk/gry	nd	2	0.00004	0.000004	0.0000004
G	blk/gry	nd	2	0.00004	0.000004	0.0000004
H	gry/blk		4000	0.08	0.008	0.0008
H	gry/blk		510	0.0102	0.00102	0.000102
H	gry/blk		30000	0.6	0.06	0.006
H	gry/blk		60000	1.2	0.12	0.012
J	gry		16000000	320	32	3.2
J	gry		22000	0.44	0.044	0.0044
J	gry		490000	9.8	0.98	0.098
J	gry		9200000	184	18.4	1.84
J	gry	>	24000000	480	48	4.8
J	gry		16000000	320	32	3.2
J	blk	*	3300	0.066	0.0066	0.00066
J	blk		9200000	184	18.4	1.84
J	blk		940000	18.8	1.88	0.188
J	blk		790000	15.8	1.58	0.158
J	gry		800000	16	1.6	0.16
J	gry		220000	4.4	0.44	0.044
J	gry		1600	0.032	0.0032	0.00032
J	gry	nd	2	0.00004	0.000004	0.0000004
J	gry		3000000	60	6	0.6
J	blk		1100000	22	2.2	0.22
J	blk		500000	10	1	0.1
K	gry		8000	0.16	0.016	0.0016
K	gry		28000	0.56	0.056	0.0056
K	gry		8000	0.16	0.016	0.0016
K	blk		5	0.0001	0.00001	0.000001
K	blk		170	0.0034	0.00034	0.000034
K	blk		110000	2.2	0.22	0.022
K	blk		5000000	100	10	1
L	gry		9000000	180	18	1.8
L	blk		17000	0.34	0.034	0.0034
L	blk	nd	2	0.00004	0.000004	0.0000004
L	blk		9000000	180	18	1.8
L	gry	<	2	0.00004	0.000004	0.0000004
L	gry	<	2	0.00004	0.000004	0.0000004
L	blk	>	16000000	320	32	3.2

Ship	Water	Qualifier	Bacteria Data	after df of 50,000	after df of 500,000	after df of 5,000,000
L	blk		300	0.006	0.0006	0.00006
L	blk	<	2	0.00004	0.000004	0.0000004
M	gry	nd	2	0.00004	0.000004	0.0000004
M	gry	nd	2	0.00004	0.000004	0.0000004
M	blk		2	0.00004	0.000004	0.0000004
M	blk	nd	2	0.00004	0.000004	0.0000004
M	blk		500000	10	1	0.1
M	gry		2200000	44	4.4	0.44
M	gry		5000000	100	10	1
M	gry		3000000	60	6	0.6
M	blk		500000	10	1	0.1
M	blk	>	16000000	320	32	3.2
M	blk		500000	10	1	0.1
N	gry		9000000	180	18	1.8
N	gry	>	2	0.00004	0.000004	0.0000004
N	blk		80	0.0016	0.00016	0.000016
N	gry		130000	2.6	0.26	0.026
N	gry		30	0.0006	0.00006	0.000006
N	gry		1200	0.024	0.0024	0.00024
N	blk	nd	2	0.00004	0.000004	0.0000004
O	gry		110000	2.2	0.22	0.022
O	gry		5	0.0001	0.00001	0.000001
O	blk		14	0.00028	0.000028	0.0000028
O	blk		4	0.00008	0.000008	0.0000008
O	blk		2800000	56	5.6	0.56
O	gry	*	9	0.00018	0.000018	0.0000018
O	blk		9000	0.18	0.018	0.0018
O	blk		5	0.0001	0.00001	0.000001
O	blk		7	0.00014	0.000014	0.0000014
O	blk	<	2	0.00004	0.000004	0.0000004
P	gry	>	16000000	320	32	3.2
P	gry		5000000	100	10	1
P	blk		16000000	320	32	3.2
P	blk		23	0.00046	0.000046	0.0000046
P	gry	>	16000000	320	32	3.2
P	gry		5000000	100	10	1
P	blk		3000000	60	6	0.6
Q	gry	nd	2	0.00004	0.000004	0.0000004
Q	blk	nd	2	0.00004	0.000004	0.0000004
Q	blk	nd	2	0.00004	0.000004	0.0000004

Ship	Water	Qualifier	Bacteria Data	after df of 50,000	after df of 500,000	after df of 5,000,000
Q	blk	nd	2	0.00004	0.000004	0.0000004
Q	blk	nd	2	0.00004	0.000004	0.0000004
Q	gry		1400000	28	2.8	0.28
Q	gry		5000000	100	10	1
Q	gry		280000	5.6	0.56	0.056
Q	blk		13	0.00026	0.000026	0.0000026
Q	blk	<	2	0.00004	0.000004	0.0000004
Q	blk	<	2	0.00004	0.000004	0.0000004
Q	blk		13000	0.26	0.026	0.0026
S	blk	nd	2	0.00004	0.000004	0.0000004
S	blk		6700	0.134	0.0134	0.00134
S	blk		260000	5.2	0.52	0.052
S	gry		1100000	22	2.2	0.22
S	gry		1100000	22	2.2	0.22
S	gry	<	2	0.00004	0.000004	0.0000004
S	blk	<	2	0.00004	0.000004	0.0000004
S	blk	<	2	0.00004	0.000004	0.0000004
S	blk		1700000	34	3.4	0.34
T	gry		350000	7	0.7	0.07
T	gry		130	0.0026	0.00026	0.000026
T	blk		170000	3.4	0.34	0.034
T	blk		5000	0.1	0.01	0.001
T	blk		5000000	100	10	1
T	gry		11000	0.22	0.022	0.0022
T	gry		900000	18	1.8	0.18
T	blk		13	0.00026	0.000026	0.0000026
T	blk	<	2	0.00004	0.000004	0.0000004
T	blk		140000	2.8	0.28	0.028
T	blk		13	0.00026	0.000026	0.0000026
U	gry		50000	1	0.1	0.01
U	gry		220000	4.4	0.44	0.044
U	gry		220000	4.4	0.44	0.044
U	blk		1700000	34	3.4	0.34
U	gry		170000	3.4	0.34	0.034
U	gry		8	0.00016	0.000016	0.0000016
U	gry	>	16000000	320	32	3.2
U	blk	>	16000000	320	32	3.2
V	blk/gry	<	2	0.00004	0.000004	0.0000004
V		<	2	0.00004	0.000004	0.0000004

Ship	**Water**	**Qualifier**	**Bacteria Data**	**after df of 50,000**	**after df of 500,000**	**after df of 5,000,000**
	blk/gry					
V		nd	2	0.00004	0.000004	0.0000004
	blk/gry					

Summary data after applying various dilution factors				**after df of 50,000**	**after df of 500,000**	**after df of 5,000,000**
			geomean =	**5.46**	**0.55**	**0.05**
			median =	**27.5**	**2.75**	**0.28**
			% > 400 =	**2%**	**0%**	**0%**
			% > 43 =	**20%**	**2%**	**0%**

M	bl/gr	2	0.00004	0.000004	0.0000004
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
M	bl/gr	1	0.00002	0.000002	0.0000002
S	bl/gr	1	0.00002	0.000002	0.0000002
S	bl/gr	1	0.00002	0.000002	0.0000002
UE	bl/gr	60	0.0012	0.00012	0.000012
UE	bl/gr	5	0.0001	0.00001	0.000001
UE	bl/gr	invalidated			
UE	bl/gr	invalidated			
		geomean =	**0.0000316**	**0.0000032**	**0.0000003**
		median =	**0.0000200**	**0.0000020**	**0.0000002**
		% > 400 =	**0%**	**0%**	**0%**
		% > 40 =	**0%**	**0%**	**0%**

Bacteria data from large cruise ships, graywater discharges, summer 2001

ship	**water**	**qualifier**	**bacteria data**	**after df of 50,000**	**after df of 500,000**	**after df of 5,000,000**
D	butch		16000000	**320**	32	3.2
D	gr		2	0.00004	0.000004	0.0000004
D	gr		70000	1.4	0.14	0.014
D	gr		90	0.0018	0.00018	0.000018
D	gr		50000	1	0.1	0.01

Bacteria data from large cruise ships, graywater discharges, summer 2001

ship	water	qualifier	bacteria data	after df of 50,000	after df of 500,000	after df of 5,000,000
D	fish		500000	10	1	0.1
D	galley		7000	0.14	0.014	0.0014
D	gr		500000	10	1	0.1
D	butch		80000	1.6	0.16	0.016
D	gr		16000000	**320**	32	3.2
D	galley		230000	4.6	0.46	0.046
N	gr		1600000	32	3.2	0.32
N	gr		30	0.0006	0.00006	0.000006
N	gr		30	0.0006	0.00006	0.000006
N	gr		1700000	34	3.4	0.34
N	gr		700000	14	1.4	0.14
N	gr		300000	6	0.6	0.06
N	gr		1	0.00002	0.000002	0.0000002
N	gr		9000000	**180**	18	1.8
N	gr		9000000	**180**	18	1.8
N	gr		2800000	**56**	5.6	0.56
N	gr		3500000	**70**	7	0.7
N	gr		16000000	**320**	32	3.2
O	gr		300000	6	0.6	0.06
O	gr		300000	6	0.6	0.06
O	galley		5000	0.1	0.01	0.001
O	gr		300000	6	0.6	0.06
O	gr		1	0.00002	0.000002	0.0000002
O	gr		170000	3.4	0.34	0.034
O	butch		1	0.00002	0.000002	0.0000002
O	gr		16000000	**320**	32	3.2
O	gr		2400000	**48**	4.8	0.48
O	fish		1	0.00002	0.000002	0.0000002
O	galley		230000	4.6	0.46	0.046
R	gr		22000	0.44	0.044	0.0044
R	gr		350000	7	0.7	0.07
R	gr		33	0.00066	0.000066	0.0000066
R	galley		50	0.001	0.0001	0.00001
R	galley		358000	7.16	0.716	0.0716
R	gr		600000	12	1.2	0.12
R	fish		624	0.01248	0.001248	0.0001248
R	butch		1	0.00002	0.000002	0.0000002
R	galley		15300000	**306**	30.6	3.06
R	gr		1	0.00002	0.000002	0.0000002
R	gr		1	0.00002	0.000002	0.0000002
R	gr		48000	0.96	0.096	0.0096
R	gr		50000	1	0.1	0.01
R	galley		30	0.0006	0.00006	0.000006
S	gr		170	0.0034	0.00034	0.000034
S	gr		1	0.00002	0.000002	0.0000002
S	gr		1	0.00002	0.000002	0.0000002
S	galley		1	0.00002	0.000002	0.0000002

Bacteria data from large cruise ships, graywater discharges, summer 2001

ship	water	qualifier	bacteria data	after df of 50,000	after df of 500,000	after df of 5,000,000
S	butch		1	0.00002	0.000002	0.0000002
S	gr		50	0.001	0.0001	0.00001
S	fish		1	0.00002	0.000002	0.0000002
S	galley		23	0.00046	0.000046	0.0000046
S	galley		30000	0.6	0.06	0.006
S	fish		1	0.00002	0.000002	0.0000002
S	gr		170000	3.4	0.34	0.034
S	galley		300000	6	0.6	0.06
S	gr		2400000	**48**	4.8	0.48
S	gr		16000000	**320**	32	3.2
			geomean =	**0.12889**	**0.01289**	**0.00129**
			median =	**1.2**	**0.12**	**0.012**
			% > 400 =	0%	0%	0%
			% > 40 =	19%	0%	0%

Appendix 8
Whole Effluent Toxicity Tests

Science Advisory Panel

for

Alaska Department of Environmental Conservation
Commercial Passenger Vessel Environmental Compliance Program

Review and Comment Regarding
Whole Effluent Toxicity Test Results

for

Five Commercial Passenger Vessels

in

Alaska

July 2002

Summary

Bioassays conducted in July 2002 by the Alaska Department of Environmental Conservation (ADEC) on a variety of commercial passenger vessel effluents indicate that acute or chronic toxic effects on marine organisms are not expected at the high dilutions that occur when vessels are underway.

The highest toxicities observed were from a graywater sample taken from a small cruise ship. The no observed effect concentration (NOEC) of 0.05% graywater effluent (a dilution factor of 2000) from this small cruise ship could be a concern if the effluent was discharged when moored, drifting or at anchor because dilution benefits are greatly reduced at such times.

The lowest toxicities were from (1) a sample of blackwater from a large cruise ship with reverse osmosis treatment and (2) an untreated blackwater sample from a small cruise ship. In fact these samples gave no toxic response even at the greatest concentration tested.

The Panel concludes that excess chlorine is the mostly likely cause of the observed toxicities.

These test results suggest tradeoffs between disinfection and chlorine toxicity and the difficulty of optimizing the amount of chlorine usage. The vessels sampled with advanced treatment technology (ultrafiltration and reverse osmosis) had very low marine organism toxicity and can safely discharge even when moored, drifting or at anchor.

Methodology

Six different effluent samples from five different cruise ships operating in Alaska waters were taken and analyzed for whole effluent toxicity (WET) in July 2002. The sampling events were arranged and scheduled in advance. The effluents covered a range of sources and treatments and came from both large and small cruise ships. The sampling, transporting, and testing followed standard EPA methods, met all test acceptability criteria, and fulfilled the requirements of the quality assurance (QA) plan. The laboratory conducting the testing was certified by the Washington Department of Ecology for conducting WET tests. Observations of conventional water quality parameters were made upon receipt at the lab. The tests were run on a dilution series of six different concentrations of effluent. Because of the high initial dilution rates associated with moving cruise ships, the dilution series started at 50% effluent and increased by a factor of 10 in each step such that the percent effluent tested progressively decreased and included concentrations of 50%, 5%, 0.5%, 0.05%, 0.005% and 0.0005% effluent. The dilution series represented concentrations that are attained in receiving waters with dilution factors of 2, 20, 200, 2,000, 20,000 and 200,000. For comparison, a typical large cruise ship discharging 200 cubic meters per hour while traveling at 6 knots (11 km/hour) would have a dilution factor of about 50,000.[47]

The test species were selected because they were the marine species most likely to be sensitive to the effluents and have well established testing protocols. Each effluent was tested using two different species for acute tests (where lethality was the effect measured) and using two different species for chronic tests (where sub-lethal effects were measured).

Validity of the test

The Science Advisory Panel has reviewed the Whole Effluent Toxicity study results[48] (hereafter called the Study) and a separate laboratory analysis of the conventional and priority pollutant concentrations of each sample[49]. The Panel concluded that the Study is a valid and useful characterization.

What do the test results say?

Table 6 from the Study summarizes the results of all the bioassay tests. It is repeated here with some changes in vessel order and column headings. For the purposes of our comments and conclusions and for ease of understanding, we focused on comparisons of no observable effects concentrations (NOEC).

[47] The Panel has developed a formula for predicting dilution/dispersion in the wake of large cruise ships.
Dilution factor = 4 x (ship width x ship draft x ship speed)/(volume discharge rate)

[48] AMEC Earth & Environmental Northwest Bioassay Laboratory. 2002. *Results of Toxicity Evaluation of Cruise Ship Wastewater Whole Effluent - Southeast Alaska.* Prepared for Alaska Department of Environmental Conservation, Juneau, AK. Project no. 31-1-11132-003

[49] Analytica Environmental Laboratories, Juneau

Numbers represent the highest effluent concentration at which the tests exhibited no observable acute or chronic effects. Values in parentheses show dilution ratios associated with the no observed effect concentrations (NOEC).

Whole Effluent Toxicity Test Results

No Observed Effect Concentration (NOEC) in % Effluent

Vessel	Treatment System	Mysid Acute NOEC	Topsmelt Acute NOEC	Bivalve Larvae NOEC	Echinoderm Fertilization NOEC
Dawn Princess Graywater	Chlorine added to collection tanks	5 (1:20)	5 (1:20)	0.5 (1:200)	0.5 (1:200)
Mercury Mixed Effluent	Reverse Osmosis	50 (1:2)	50 (1:2)	50 (>1:2)	50 (1:2)
Volendam Mixed Effluent	Aerated Membrane (Ultrafiltration)	50 (1:2)	5 (1:20)	5 (1:20)	5 (1:20)
Kennicott Mixed Effluent	Macerator/ Chlorinator	5 (1:20)	5 (1:20)	5 (1:20)	0.5 (1:200)
Yorktown Clipper Graywater	Chlorine injection	0.5 (1:200)	0.5 (1:200)	0.5 (1:200)	0.05 (1:2000)
Yorktown Clipper Blackwater	Macerator/ Chlorinator	50 (>1:2)	50 (1:2)	50 (1:2)	50 (1:2)

What do the test results mean?

Whole Effluent Toxicity (WET) testing is an alternative to directly analyzing environmental samples for individual constituents. WET testing addresses the effect that simultaneous exposure to a mixture of pollutants has on an organism. A full description of the WET process is provided as an appendix to these comments.

In summary, samples from the Mercury and of the Yorktown blackwater did not demonstrate any toxicity at any concentration. The Volendam sample demonstrated an effect at 50% (one part seawater to one part wastewater) for the Topsmelt acute and both chronic test species. The Dawn Princess and the Kennicott demonstrated some effect at 50% concentration in the acute test and some effect at 5% wastewater concentration in the chronic tests. The Yorktown graywater sample exhibited the most observable toxicity effect of all vessels tested.

If the wastewater effluents were all from large cruise ships that were discharging underway, the observed WET values would not be of concern because of the high dilution rates[1]. Because the greatest chronic toxicity measurement was observed from a small ship which discharges continuously (Yorktown Clipper graywater), attaining the necessary dilution might be a concern.

The chronic toxicity of the Yorktown Clipper graywater and the Kennicott mixed effluent may be explained by the excessive chlorination of the effluent. Alaska's water quality standard for total residual chlorine is 2 ppb for salmonids and 10 ppb for other organisms. The total residual chlorine in the Yorktown Clipper graywater and Kennicott mix was 16,200 ppb and 30,300 ppb, respectively. These chlorine concentrations support the NOEC measured for these two vessels, where effects were observed at lower concentrations than those of other vessels and effluents. The observed toxicity of the Dawn Princess graywater is not readily explained. There was no residual chlorine in the sample, but nevertheless, the toxicity of the Dawn Princess graywater would not be significant at the dilutions estimated for cruise ships discharging underway.

An interesting observation from the above data set is the lack of toxicity of the Yorktown Clipper blackwater sample. When the sample was drawn, it was evident that the treatment system was not functioning properly. The bacteria concentration of 2,400 MPN/100 ml indicates that the effluent must have been chlorinated, but not with enough chlorine to have any residual chlorine left at the time of the test. For all four tests, the sample exhibited no acute or chronic toxicity at the highest concentration (50%).

Conclusions of the Science Advisory Panel

The bioassay (WET test) conducted by AMEC Earth & Environmental on behalf of the Alaska Department of Environmental Conservation is valid and useful to the Panel's study of the potential for impacts or effects of commercial passenger vessel wastewater discharges.

The various effluents tested and analyzed would be expected to impart no acute or chronic toxic effects to marine organisms at the high dilutions that occur when vessels are underway.

The highest toxicities were observed from a graywater sample taken from a small cruise ship. The highly chlorinated graywater effluent from this small cruise ship could be a concern if the effluent was discharged when moored, drifting or at anchor because dilution benefits are greatly reduced at such times.

The effluents from the vessel employing reverse osmosis advanced treatment technology (Mercury) would not be expected to impart observable effects on marine organisms if discharged in port.

The effluents from the vessel employing ultrafiltration advanced treatment technology (Volendam) would not be expected to impart observable effects on marine organisms if discharged in port, provided the effluent is diluted by a factor 20. The Panel believes this

mixing rate is easily achieved for large cruise ships, given the discharge velocity required to overcome the static head pressure at the depth of the discharge port[50].

This study highlights the trade-offs created when chlorine is used for disinfection.

Science Advisory Panel Members participating in the preparation of these comments

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October 2, 2002

[50] We made the following assumptions regarding the dilution achieved when a vessel is at rest. One is that the effluent is being pumped. One can also assume that the discharge pipe diameter would be no larger than 8 inches. The EPA approved dilution-modeling CORMIX model shows that at a discharge rate of $50m^3$/hr yields a dilution factor of 36 at a distance about 4.5m from the ship, and a dilution factor of 50 at 7m from the ship after 43 seconds.

Appendix

Whole Effluent Toxicity (WET) Testing

Theory, Procedures, and Process

Whole Effluent Toxicity (WET) testing is an alternative to directly analyzing environmental samples for individual constituents. In WET testing, impact of a discharge stream on the environment can be evaluated in terms of its short (acute) or long-term (chronic) lethal or reproductive effects on indigenous animal species. Test organisms are exposed to various dilutions. Conditions of exposure can be varied based on the desired type of response. In a static non-renewal test, the test organisms are exposed to a single portion of the test solution for the duration of the test. In a static renewal test, the test organisms are exposed to fresh changes of the test water every day for the duration of the test. In a flow through test, the test organisms are continuously exposed to fresh batches, or mixes of test solution. Both the acute and the chronic tests were static. Effect of the exposure is measured in terms of a no observable effect concentration (NOEC) and a lowest observable effect concentration (LOEC) based on whether there is a statistical difference between controls and test samples. Additionally, a lethal concentration (LC) or a dose response curve can be calculated from the test results. LC is the concentration of the test material that kills a specified percentage of the test organisms over the observation time. An example of how the LC is expressed would be a "48-hr LC_{50}." This is the concentration of the test sample that resulted in death of 50% of the organisms after a 48-hour exposure. A dose response expresses the response of the organism to a toxicant based upon body weight or dilution. The curve plots percent response verses log dose.[51] Sub-lethal effect concentrations (EC) can be similarly described.

This WET testing investigation examined the toxicity of six effluent samples from five commercial cruise ships using marine organisms. Mysid shrimp (*Mysidopsis bahia)* and Topsmelt (*Atherinops affinis)* were selected as the test organisms for the acute testing. Survival was evaluated after a 48-hour exposure period to the Mysid shrimp and a 96-hour exposure period to the Topsmelt. The bivalve *Mytilus galloprovincialis* and the echinoderm *Strongylocentrotus purpuratus* were used as the test organisms for the chronic tests. Test concentrations examined were 50%, 5%, 0.5%, 0.05%, 0.005%, and 0.0005% of the effluent.

EPA has a method for calculating a concentration from an LC_{50} that represents "virtually no mortality." However, the reported acute NOECs are sufficient for our evaluation. The acute NOECs varied from 50% to 0.5% effluent. The lowest acute NOEC of 0.5% was for a heavily chlorinated effluent. Note that a 0.5% effluent concentration is attained after a dilution factor of only 200. Discharges from moving cruise ships attain much greater dilutions and acute whole effluent toxicity is not a concern for discharges when moving.

[51] Smith, Roy-Keith, Handbook of Environmental Analysis, Fourth Edition, Genium Publishing Corporation, 1999.

The chronic bioassay results have NOECs varying from 50% to 0.05% effluent. Alaska has a water quality standard of 1 chronic toxic unit (TU_c). The chronic toxic units for a discharge may be determined by dividing 100 by the NOEC. Consequently, the chronic toxic units observed in the above effluents varied from 2 to 2,000. Following Alaska and EPA's approach, dilution is considered in determining where the 1 TU_c standard is to be applied. The chronic toxic units actually are the same as the amount of dilution needed to meet the 1 TU_c standard.

For large cruise ships traveling at a speed of at least 6 knots, a dilution factor of 50,000 is considered reasonable and conservative. For small cruise ships also traveling at 6 knots it may be around 37,500. It is clear that as soon as effluent is entrained in turbulence behind the stern of a ship moving at 6 knots or greater, within a minute or so a dilution factor substantially greater than 2000 will have been achieved for either small or large vessels. In terms of the NOEC, this means that the concentration of the effluent in seawater will be substantially less than 0.05% at that same location. It is also evident that small cruise ships will require better methods to ensure highly chlorinated discharges are not released while the vessels are stationary, or (preferably) traveling at less than 6 knots.

Appendix 9
Mussel Contaminants

Table D-1a: PAH Values in Alaskan Mussels

SEQ	248	249	250	254	257	Mean Alaska	Median	Min	Max	STDEV	n
Site	**KTMP**	**NBES**	**PVMC**	**UISB**	**CIHS**						
Year	**2001**	**2001**	**2001**	**2001**	**2001**						
Sample	**NST0854**	**NST0863**	**NST0856**	**NST0855**	**NST0859**						
Unit: ppb (ug/kg) dw											
Naphthalene	8.60	14.10	11.90	11.70	10.20	**11.30**	11.70	8.60	14.10	2.05	5
C1-Naphthalenes	4.10	6.10	6.60	6.00	5.60	**5.68**	6.00	4.10	6.60	0.95	5
C2-Naphthalenes	3.70	5.00	5.30	4.90	7.10	**5.20**	5.00	3.70	7.10	1.22	5
C3-Naphthalenes	2.00	0.00	0.00	0.00	8.40	**2.08**	0.00	0.00	8.40	3.64	5
C4-Naphthalenes	0.00	0.00	0.00	0.00	12.50	**2.50**	0.00	0.00	12.50	5.59	5
Biphenyl	1.90	3.10	3.20	4.60	2.30	**3.02**	3.10	1.90	4.60	1.04	5
Acenaphthylene	0.40	0.90	0.40	0.30	0.60	**0.52**	0.40	0.30	0.90	0.24	5
Acenaphthene	0.60	1.60	0.40	0.70	1.60	**0.98**	0.70	0.40	1.60	0.58	5
Fluorene	0.70	1.10	0.70	0.70	1.80	**1.00**	0.70	0.70	1.80	0.48	5
C1-Fluorenes	0.00	0.00	0.00	0.00	4.10	**0.82**	0.00	0.00	4.10	1.83	5
C2-Fluorenes	0.00	0.00	0.00	0.00	5.40	**1.08**	0.00	0.00	5.40	2.41	5
C3-Fluorenes	0.00	0.00	0.00	0.00	4.00	**0.80**	0.00	0.00	4.00	1.79	5
Phenanthrene	6.30	21.00	10.40	2.50	13.10	**10.66**	10.40	2.50	21.00	7.05	5
Anthracene	0.20	1.70	0.20	0.40	1.10	**0.72**	0.40	0.20	1.70	0.66	5
C1-Phenanthrenes/Anthracenes	2.50	5.30	5.10	1.80	5.90	**4.12**	5.10	1.80	5.90	1.84	5
C2-Phenanthrenes/Anthracenes	0.00	0.00	0.00	0.00	7.00	**1.40**	0.00	0.00	7.00	3.13	5
C3-Phenanthrenes/Anthracenes	0.00	0.00	0.00	0.00	3.80	**0.76**	0.00	0.00	3.80	1.70	5
C4-Phenanthrenes/Anthracenes	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Dibenzothiophene	0.30	0.70	0.90	0.30	0.80	**0.60**	0.70	0.30	0.90	0.28	5

SEQ	248	249	250	254	257	Mean Alaska	Median	Min	Max	STDEV	n
Site	**KTMP**	**NBES**	**PVMC**	**UISB**	**CIHS**						
Year	**2001**	**2001**	**2001**	**2001**	**2001**						
Sample	**NST0854**	**NST0863**	**NST0856**	**NST0855**	**NST0859**						
Unit: ppb (ug/kg) dw											
C1-Dibenzothiophenes	0.00	0.00	1.70	0.00	2.50	**0.84**	0.00	0.00	2.50	1.18	5
C2-Dibenzothiophenes	0.00	0.00	3.10	0.00	4.30	**1.48**	0.00	0.00	4.30	2.07	5
C3-Dibenzothiophenes	0.00	0.00	0.00	0.00	1.80	**0.36**	0.00	0.00	1.80	0.80	5
Fluoranthene	2.70	11.60	3.60	0.50	6.30	**4.94**	3.60	0.50	11.60	4.26	5
Pyrene	1.10	3.30	1.50	0.30	5.80	**2.40**	1.50	0.30	5.80	2.20	5
C1-Fluoranthenes/Pyrenes	1.50	5.10	0.00	0.00	2.60	**1.84**	1.50	0.00	5.10	2.13	5
Benzo(a)anthracene	1.20	5.90	1.30	0.20	1.20	**1.96**	1.20	0.20	5.90	2.25	5
Chrysene	4.10	9.70	5.20	1.00	2.10	**4.42**	4.10	1.00	9.70	3.38	5
C1-Chrysenes	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
C2-Chrysenes	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
C3-Chrysenes	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
C4-Chrysenes	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Benzo(b)fluoranthene	0.00	3.20	0.00	0.00	0.00	**0.64**	0.00	0.00	3.20	1.43	5
Benzo(k)fluoranthene	0.00	4.40	0.00	0.00	0.00	**0.88**	0.00	0.00	4.40	1.97	5
Benzo(e)pyrene	1.40	2.10	0.00	0.00	0.00	**0.70**	0.00	0.00	2.10	0.99	5
Benzo(a)pyrene	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Perylene	0.00	0.00	0.00	4.70	6.80	**2.30**	0.00	0.00	6.80	3.24	5
Indeno(1,2,3-c,d)pyrene	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Dibenzo(a,h)anthracene	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
2-Methylnaphthalene	3.90	5.70	6.00	5.70	5.60	**5.38**	5.70	3.90	6.00	0.84	5
1-Methylnaphthalene	2.40	3.60	4.10	3.40	2.90	**3.28**	3.40	2.40	4.10	0.65	5

SEQ	248	249	250	254	257	Mean Alaska	Median	Min	Max	STDEV	n
Site	**KTMP**	**NBES**	**PVMC**	**UISB**	**CIHS**						
Year	**2001**	**2001**	**2001**	**2001**	**2001**						
Sample	**NST0854**	**NST0863**	**NST0856**	**NST0855**	**NST0859**						
Unit: ppb (ug/kg) dw											
2,6-Dimethylnaphthalene	1.60	1.60	2.20	1.70	3.20	**2.06**	1.70	1.60	3.20	0.68	5
Benzo(g,h,i)perylene	0.40	0.40	0.00	0.00	0.00	**0.16**	0.00	0.00	0.40	0.22	5
1,6,7-Trimethylnaphthalene	0.30	0.00	0.60	0.40	1.70	**0.60**	0.40	0.00	1.70	0.65	5
1-Methylphenanthrene	0.60	1.10	1.20	0.60	2.00	**1.10**	1.10	0.60	2.00	0.57	5
NS&T TPAH	**44.00**	**106.00**	**62.00**	**41.00**	**129.00**	**76.40**	**62.00**	**41.00**	**129.00**	**39.22**	**5**
TPAH (44)	**52.50**	**118.30**	**75.60**	**52.40**	**144.10**	**88.58**	**75.60**	**52.40**	**144.10**	**41.06**	**5**
FFPI numerator	**28.20**	**53.30**	**45.70**	**27.90**	**98.30**	**50.68**	**45.70**	**27.90**	**98.30**	**28.83**	**5**
FFPI (52/51)	**0.54**	**0.45**	**0.60**	**0.53**	**0.68**	**0.56**	**0.54**	**0.45**	**0.68**	**0.09**	**5**

Table D-1b: PAH Values in West Coast Mussels

	Mean West	Median	Min	Max	STDEV	Count	Ratio AK to West Coast Mean
Unit: ppb (ug/kg) dw							
Naphthalene	**16.70**	11.60	5.40	174	22.51	58	0.68
C1-Naphthalenes	**15.80**	7.35	2.40	348	45.70	58	0.36
C2-Naphthalenes	**14.93**	5.13	0.00	360	47.33	58	0.35
C3-Naphthalenes	**13.69**	3.60	0.00	241	33.62	58	0.15
C4-Naphthalenes	**10.36**	2.95	0.00	87	18.50	58	0.24
Biphenyl	**7.48**	3.50	1.50	188	24.38	58	0.40
Acenaphthylene	**4.30**	1.00	0.00	60	9.71	58	0.12
Acenaphthene	**27.50**	1.28	0.00	1060	141.28	58	0.04
Fluorene	**38.92**	1.90	0.40	1600	211.32	58	0.03
C1-Fluorenes	**11.15**	0.00	0.00	304	41.40	58	0.07
C2-Fluorenes	**14.10**	0.00	0.00	194	34.23	58	0.08
C3-Fluorenes	**16.60**	0.00	0.00	220	38.22	58	0.05
Phenanthrene	**191.94**	20.15	2.90	6140	817.59	58	0.06
Anthracene	**28.45**	2.50	0.00	737	102.06	58	0.03
C1-Phenanthrenes/Anthracenes	**81.60**	9.88	0.00	1870	258.90	58	0.05
C2-Phenanthrenes/Anthracenes	**66.50**	10.25	0.00	952	151.47	58	0.02
C3-Phenanthrenes/Anthracenes	**41.17**	7.60	0.00	427	78.73	58	0.02
C4-Phenanthrenes/Anthracenes	**12.00**	0.00	0.00	107	23.44	58	0.00
Dibenzothiophene	**13.46**	1.30	0.20	473	62.51	58	0.04
C1-Dibenzothiophenes	**10.34**	1.60	0.00	180	27.85	58	0.08
C2-Dibenzothiophenes	**18.86**	3.30	0.00	236	40.62	58	0.08

	Mean West	Median	Min	Max	STDEV	Count	Ratio AK to West Coast Mean
Unit: ppb (ug/kg) dw							
C3-Dibenzothiophenes	**18.29**	1.38	0.00	157	35.30	58	0.02
Fluoranthene	**325.49**	20.60	0.50	7250	1022.76	58	0.02
Pyrene	**192.62**	16.50	0.30	4290	602.10	58	0.01
C1-Fluoranthenes/Pyrenes	**118.61**	9.65	0.00	2620	370.69	58	0.02
Benzo(a)anthracene	**113.27**	5.65	0.30	3370	453.42	58	0.02
Chrysene	**148.04**	16.00	1.00	3240	449.65	58	0.03
C1-Chrysenes	**55.53**	2.35	0.00	1520	205.81	58	0.00
C2-Chrysenes	**14.40**	0.00	0.00	359	50.12	58	0.00
C3-Chrysenes	**0.82**	0.00	0.00	35	4.70	58	0.00
C4-Chrysenes	**0.17**	0.00	0.00	6	0.91	58	0.00
Benzo(b)fluoranthene	**75.38**	5.55	0.00	1680	238.12	58	0.01
Benzo(k)fluoranthene	**83.69**	5.40	0.00	2410	323.18	58	0.01
Benzo(e)pyrene	**63.78**	7.50	0.00	1480	203.39	58	0.01
Benzo(a)pyrene	**27.32**	1.10	0.00	814	110.34	58	0.00
Perylene	**14.02**	5.35	0.00	268	36.59	58	0.16
Indeno(1,2,3-c,d)pyrene	**12.97**	1.85	0.00	335	45.04	58	0.00
Dibenzo(a,h)anthracene	**3.17**	0.25	0.00	89	11.89	58	0.00
Benzo(g,h,i)perylene	**9.84**	2.60	0.00	205	27.74	58	0.02
2-Methylnaphthalene	**18.19**	7.85	2.40	379	50.47	58	0.30
1-Methylnaphthalene	**6.94**	2.95	1.30	181	23.52	58	0.47
2,6-Dimethylnaphthalene	**7.73**	2.40	0.90	202	26.50	58	0.27
1,6,7-Trimethylnaphthalene	**2.58**	0.80	0.20	40	5.89	58	0.23

	Mean West	Median	Min	Max	STDEV	Count	Ratio AK to West Coast Mean
Unit: ppb (ug/kg) dw							
1-Methylphenanthrene	**12.84**	1.85	0.00	288	39.31	58	0.09
TPAH (44)	**1981.54**	**251.13**	**34.80**	**46698**	**6357**	**58**	**0.04**
FFPI numerator	**664.34**	**119.55**	**20.70**	**15513**	**2094**	**58**	**0.08**
FFPI (52/51)	**0.45**	**0.45**	**0.16**	**0.88**	**0.16**	**58**	**1.24**
NS&T TPAH	**1933.30**	**231.05**	**28.40**	**45608**	**6218**	**58**	**0.04**

Table D-2a: Organic Compounds in Alaska Mussels

SEQ	**248**	**249**	**250**	**254**	**257**						
SITE	**KTMP**	**NBES**	**PVMC**	**UISB**	**CIHS**						
General Loc	**Ketchikan**	**Skagway**	**Port Valdez**	**Unakwik Inlet**	**Cook Inlet**						
Specific	**Mountain Point**	**East Side**	**Mineral Creek FLats**	**Siwash Bay**	**Homer Spit**						
LAT	**55.301**	**59.456**	**61.136**	**60.956**	**59.624**						
LONG	**131.558**	**135.339**	**146.463**	**147.658**	**151.451**						
Sample Name	**NST0854**	**NST0863**	**NST0856**	**NST0855**	**NST0859**						
Coll Date	**3/28/2001**	**4/19/2001**	**3/3/2001**	**3/29/2001**	**4/8/2001**						
YEAR	**2001**	**2001**	**2001**	**2001**	**2001**	**Alaska**	**Alaska**	**Alaska**	**Alaska**	**Alaska**	**Alaska**
Unit: ppb or ug/kg (ng/g) dw						**Mean**	**Median**	**Min**	**Max**	**Stdev**	**n**
% Dry	16.95	12.11	12.16	13.73	14.29	**13.85**	13.73	12.11	16.95	1.98	5
% Moisture	83.05	87.89	87.84	86.27	85.71	**86.15**	86.27	83.05	87.89	1.98	5
% Lipid Based (dry)	4.76	4.35	2.62	3.54	3.99	**3.85**	3.99	2.62	4.76	0.82	5
% Lipid Based (wet)	0.81	0.53	0.32	0.49	0.57	**0.54**	0.53	0.32	0.81	0.18	5
Aldrin	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Dieldrin	0.33	0.85	0.23	0.39	0.38	**0.44**	0.38	0.23	0.85	0.24	5
Endrin	0.00	0.12	0.00	0.00	0.00	**0.02**	0.00	0.00	0.12	0.05	5
Heptachlor	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Heptachlor-Epoxide	0.16	0.36	0.23	0.20	0.19	**0.23**	0.20	0.16	0.36	0.08	5
Oxychlordane	0.08	0.49	0.00	0.00	0.10	**0.13**	0.08	0.00	0.49	0.20	5
Alpha-Chlordane	0.33	0.73	0.23	0.30	0.38	**0.39**	0.33	0.23	0.73	0.19	5
Gamma-Chlordane	0.08	0.24	0.12	0.10	0.10	**0.13**	0.10	0.08	0.24	0.07	5
Trans-Nonachlor	0.24	0.85	0.23	0.20	0.38	**0.38**	0.24	0.20	0.85	0.27	5
Cis-Nonachlor	0.08	0.36	0.12	0.10	0.00	**0.13**	0.10	0.00	0.36	0.14	5

SEQ	248	249	250	254	257						
SITE	KTMP	NBES	PVMC	UISB	CIHS						
General Loc	Ketchikan	Skagway	Port Valdez	Unakwik Inlet	Cook Inlet						
Specific	Mountain Point	East Side	Mineral Creek FLats	Siwash Bay	Homer Spit						
LAT	55.301	59.456	61.136	60.956	59.624						
LONG	131.558	135.339	146.463	147.658	151.451						
Sample Name	NST0854	NST0863	NST0856	NST0855	NST0859						
Coll Date	3/28/2001	4/19/2001	3/3/2001	3/29/2001	4/8/2001						
YEAR	2001	2001	2001	2001	2001	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
Unit: ppb or ug/kg (ng/g) dw						Mean	Median	Min	Max	Stdev	n
Alpha-HCH	1.06	1.21	0.93	0.99	1.14	**1.07**	1.06	0.93	1.21	0.11	5
Beta-HCH	0.73	0.73	0.00	0.59	0.86	**0.58**	0.73	0.00	0.86	0.34	5
Delta-HCH	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Gamma-HCH	0.33	0.49	0.23	0.39	0.48	**0.38**	0.39	0.23	0.49	0.11	5
2,4'-DDD	0.00	0.49	0.00	0.00	0.00	**0.10**	0.00	0.00	0.49	0.22	5
4,4'-DDD	0.41	0.49	0.35	0.30	0.38	**0.38**	0.38	0.30	0.49	0.07	5
2,4'-DDE	0.16	0.24	0.12	0.10	0.19	**0.16**	0.16	0.10	0.24	0.06	5
4,4'-DDE	0.41	1.21	0.35	0.20	0.29	**0.49**	0.35	0.20	1.21	0.41	5
2,4'-DDT	0.16	0.61	0.23	0.20	0.19	**0.28**	0.20	0.16	0.61	0.19	5
4,4'-DDT	0.00	0.24	0.12	0.10	0.10	**0.11**	0.10	0.00	0.24	0.09	5
1,2,3,4-Tetrachlorobenzene	0.08	0.00	0.00	0.30	0.10	**0.09**	0.08	0.00	0.30	0.12	5
1,2,4,5-Tetrachlorobenzene	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Hexachlorobenzene	0.49	0.97	0.58	0.49	0.48	**0.60**	0.49	0.48	0.97	0.21	5
Pentachloroanisole	0.24	0.24	0.23	0.20	0.29	**0.24**	0.24	0.20	0.29	0.03	5
Pentachlorobenzene	0.08	0.12	0.00	0.10	0.10	**0.08**	0.10	0.00	0.12	0.05	5

SEQ	248	249	250	254	257						
SITE	KTMP	NBES	PVMC	UISB	CIHS						
General Loc	Ketchikan	Skagway	Port Valdez	Unakwik Inlet	Cook Inlet						
Specific	Mountain Point	East Side	Mineral Creek FLats	Siwash Bay	Homer Spit						
LAT	55.301	59.456	61.136	60.956	59.624						
LONG	131.558	135.339	146.463	147.658	151.451						
Sample Name	NST0854	NST0863	NST0856	NST0855	NST0859						
Coll Date	3/28/2001	4/19/2001	3/3/2001	3/29/2001	4/8/2001						
YEAR	2001	2001	2001	2001	2001	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
Unit: ppb or ug/kg (ng/g) dw						Mean	Median	Min	Max	Stdev	n
Endosulfan II	0.08	0.24	0.12	0.10	0.10	**0.13**	0.10	0.08	0.24	0.07	5
Endosulfan I	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Endosulfan Sulfate	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Mirex	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Chlorpyrifos	0.00	0.73	0.70	0.30	0.29	**0.40**	0.30	0.00	0.73	0.31	5
PCB8/5	0.00	0.85	0.93	0.59	0.67	**0.61**	0.67	0.00	0.93	0.37	5
PCB18	0.00	0.24	0.00	0.00	0.10	**0.07**	0.00	0.00	0.24	0.11	5
PCB28	0.00	0.49	0.35	0.10	0.00	**0.19**	0.10	0.00	0.49	0.22	5
PCB44	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
PCB52	0.33	0.73	0.35	0.20	0.38	**0.40**	0.35	0.20	0.73	0.20	5
PCB66	0.00	0.12	0.00	0.00	0.00	**0.02**	0.00	0.00	0.12	0.05	5
PCB101/90	0.33	0.73	0.12	0.20	0.38	**0.35**	0.33	0.12	0.73	0.24	5
PCB105	0.16	0.24	0.12	0.10	0.10	**0.14**	0.12	0.10	0.24	0.06	5
PCB118	0.16	0.24	0.12	0.00	0.10	**0.12**	0.12	0.00	0.24	0.09	5
PCB128	0.08	0.00	0.00	0.00	0.00	**0.02**	0.00	0.00	0.08	0.04	5

SEQ	248	249	250	254	257						
SITE	KTMP	NBES	PVMC	UISB	CIHS						
General Loc	Ketchikan	Skagway	Port Valdez	Unakwik Inlet	Cook Inlet						
Specific	Mountain Point	East Side	Mineral Creek FLats	Siwash Bay	Homer Spit						
LAT	55.301	59.456	61.136	60.956	59.624						
LONG	131.558	135.339	146.463	147.658	151.451						
Sample Name	NST0854	NST0863	NST0856	NST0855	NST0859						
Coll Date	3/28/2001	4/19/2001	3/3/2001	3/29/2001	4/8/2001						
YEAR	2001	2001	2001	2001	2001	Alaska	Alaska	Alaska	Alaska	Alaska	Alaska
Unit: ppb or ug/kg (ng/g) dw						Mean	Median	Min	Max	Stdev	n
PCB138	0.57	1.21	0.46	0.30	0.57	**0.62**	0.57	0.30	1.21	0.35	5
PCB153/132/168	0.73	1.46	0.35	0.20	0.57	**0.66**	0.57	0.20	1.46	0.49	5
PCB170/190	0.41	0.85	1.16	0.59	0.38	**0.68**	0.59	0.38	1.16	0.33	5
PCB180	0.65	2.67	0.93	0.20	0.19	**0.93**	0.65	0.19	2.67	1.02	5
PCB187	0.16	0.24	0.12	0.10	0.10	**0.14**	0.12	0.10	0.24	0.06	5
PCB195/208	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
PCB206	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
PCB209	0.08	0.00	0.00	0.00	0.00	**0.02**	0.00	0.00	0.08	0.04	5
Total HCH	**2.12**	**2.43**	**1.16**	**1.97**	**2.47**	**2.03**	**2.12**	**1.16**	**2.47**	**0.53**	**5**
Total Chlordane	**0.98**	**3.03**	**0.93**	**0.89**	**1.14**	**1.39**	**0.98**	**0.89**	**3.03**	**0.92**	**5**
Total DDT	**1.14**	**3.27**	**1.16**	**0.89**	**1.14**	**1.52**	**1.14**	**0.89**	**3.27**	**0.99**	**5**
Total PCB	**10.22**	**24.23**	**13.13**	**7.81**	**9.89**	**13.06**	**10.22**	**7.81**	**24.23**	**6.53**	**5**

Table D-2b: Organic Compounds in West Coast Mussels

Unit: ppb or ug/kg (ng/g) dw	Mean	Median	Min	Max	Stdev	n
% Dry	**15.70**	15.28	8.28	22.16	2.90	58
% Moisture	**84.30**	84.73	77.84	91.72	2.90	58
% Lipid Based (dry)	**5.05**	4.69	2.68	13.15	1.86	58
% Lipid Based (wet)	**0.80**	0.73	0.32	2.25	0.35	58
Aldrin	**0.03**	NA	0.00	1.66	0.22	58
Dieldrin	**7.32**	2.59	0.42	183.82	24.34	58
Endrin	**0.54**	0.11	0.00	8.98	1.58	58
Heptachlor	**0.30**	0.00	0.00	13.52	1.78	58
Heptachlor-Epoxide	**0.76**	0.68	0.00	3.05	0.54	58
Oxychlordane	**0.96**	0.48	0.09	8.60	1.41	58
Alpha-Chlordane	**5.21**	3.24	0.36	44.16	6.66	58
Gamma-Chlordane	**3.72**	1.25	0.00	46.90	7.08	58
Trans-Nonachlor	**3.23**	1.46	0.18	30.55	5.05	58
Cis-Nonachlor	**1.75**	0.75	0.00	10.46	2.59	58
Alpha-HCH	**1.20**	1.07	0.00	3.43	0.69	58
Beta-HCH	**0.89**	0.72	0.14	3.92	0.60	58
Delta-HCH	**0.03**	0.00	0.00	0.16	0.05	58
Gamma-HCH	**0.42**	0.33	0.10	1.33	0.25	58
2,4'-DDD	**3.03**	1.35	0.00	28.89	4.68	58
4,4'-DDD	**6.27**	1.73	0.26	62.61	10.93	58
2,4'-DDE	**3.94**	0.67	0.00	51.63	9.70	58
4,4'-DDE	**43.32**	10.74	1.16	341.86	76.76	58
2,4'-DDT	**4.09**	0.64	0.00	152.03	19.93	58
4,4'-DDT	**6.88**	0.95	0.00	193.35	26.62	58
1,2,3,4-Tetrachlorobenzene	**0.04**	0.00	0.00	0.52	0.09	58
1,2,4,5-Tetrachlorobenzene	**0.15**	0.00	0.00	3.21	0.65	58
Hexachlorobenzene	**0.64**	0.37	0.00	10.91	1.41	58
Pentachloroanisole	**1.34**	1.09	0.30	4.13	0.82	58
Pentachlorobenzene	**0.24**	0.09	0.00	2.02	0.42	58
Endosulfan II	**1.16**	0.10	0.00	18.31	3.37	58

Unit: ppb or ug/kg (ng/g) dw	Mean	Median	Min	Max	Stdev	n
Endosulfan I	**1.50**	0.25	0.00	18.50	3.75	58
Endosulfan Sulfate	**0.17**	0.00	0.00	2.81	0.45	58
Mirex	**0.07**	0.00	0.00	0.77	0.15	58
Chlorpyrifos	**0.39**	0.27	0.00	3.78	0.65	58
PCB8/5	**0.11**	0.00	0.00	2.02	0.36	58
PCB18	**0.59**	0.23	0.00	5.17	1.02	58
PCB28	**0.83**	0.31	0.00	7.50	1.49	58
PCB44	**1.41**	0.53	0.00	12.12	2.32	58
PCB52	**4.95**	2.93	0.00	25.55	5.77	58
PCB66	**1.88**	0.61	0.00	24.76	4.16	58
PCB101/90	**7.55**	2.67	0.39	83.01	14.86	58
PCB105	**1.80**	0.67	0.06	23.46	3.66	58
PCB118	**6.02**	2.16	0.06	74.46	12.71	58
PCB128	**1.64**	0.55	0.00	20.23	3.44	58
PCB138	**11.15**	4.27	0.32	151.02	24.93	58
PCB153/132/168	**16.78**	6.71	0.58	159.65	29.54	58
PCB170/190	**1.92**	1.32	0.10	9.45	1.83	58
PCB180	**5.54**	3.47	0.25	19.97	5.43	58
PCB187	**4.78**	1.89	0.10	50.22	9.43	58
PCB195/208	**0.00**	0.00	0.00	0.15	0.02	58
PCB206	**0.06**	0.00	0.00	1.72	0.23	58
PCB209	**0.08**	0.00	0.00	0.86	0.17	58
Total HCH	**2.54**	**2.23**	**0.29**	**8.67**	**1.44**	**58**
Total Chlordane	**15.92**	**9.34**	**1.51**	**148.6**	**22.47**	**58**
Total DDT	**64.90**	**16.91**	**2.01**	**491.5**	**112.87**	**58**
Total PCB	**148.65**	**65.40**	**7.46**	**1429.4**	**247.72**	**58**

Table D-3a: Metals in Alaska Mussels during 2000 and 2001

SEQ	248	249	250	254	257	Mean	All	All	All	All	All
SITE	KTMP	NBES	PVMC	UISB	CIHS	Alaska	Alaska	Alaska	Alaska	Alaska	AK
YEAR	2001	2001	2001	2001	2001	Mean	Median	Min	Max	Stdev	n
Unit: ppm (mg/kg) dw											
Silver (AG)	0.901	0.301	0.684	1.696	0.151	**0.747**	0.684	0.151	1.696	0.609	5
Aluminum (AL)	62	241	1149	756	1011	**644**	756	62	1149	475	5
Arsenic (As)	13.90	12.00	14.00	15.00	12.90	**13.56**	13.90	12.00	15.00	1.15	5
Cadmium (CD)	5.76	6.28	3.48	4.17	1.95	**4.33**	4.17	1.95	6.28	1.75	5
Chromium (CR)	0.38	0.71	2.09	6.01	1.21	**2.08**	1.21	0.38	6.01	2.29	5
Copper (CU)	7.17	7.31	7.52	10.75	9.28	**8.41**	7.52	7.17	10.75	1.56	5
Iron (FE)	151	386	1368	774	1133	**762**	774	151	1368	505	5
Mercury (HG)	0.092	0.116	0.083	0.154	0.106	**0.110**	0.106	0.083	0.154	0.028	5
Manganese (MN)	9.37	14.14	28.12	25.89	27.20	**20.94**	25.89	9.37	28.12	8.59	5
Nickel (NI)	1.51	5.46	7.03	3.19	2.48	**3.93**	3.19	1.51	7.03	2.26	5
Lead (PB)	0.372	1.777	1.346	1.054	0.654	**1.041**	1.054	0.372	1.777	0.555	5
Selenium (SE)	4.64	5.74	3.73	8.09	4.32	**5.30**	4.64	3.73	8.09	1.72	5
Tin (SN)	0.260	0.067	0.993	0.072	0.003	**0.279**	0.072	0.003	0.993	0.411	5
Zinc (ZN)	91.4	66.8	48.2	111.4	92.0	**82.0**	91.4	48.2	111.4	24.6	5
Monobutyltin MBT)	0.00	3.72	2.27	0.00	0.00	**1.20**	0.00	0.00	3.72	1.72	5
Dibutyltin DBT)	0.00	8.96	5.57	0.00	2.14	**3.33**	2.14	0.00	8.96	3.88	5
Tributyltin (TBT)	2.78	7.10	7.43	2.93	4.60	**4.97**	4.60	2.78	7.43	2.22	5
Tetrabutyltin (TetBT)	0.00	0.00	0.00	0.00	0.00	**0.00**	0.00	0.00	0.00	0.00	5
Total Butyltins (Sum BT)	2.78	19.78	15.27	2.93	6.74	**9.50**	6.74	2.78	19.78	7.66	5

Table D-3b: Metals in West Coast Mussels during 2000 and 2001

SEQ	**West**	West	West	West	West		Ratio
SITE	**Coast**	Coast	Coast	Coast	Coast		AK/West
YEAR	**Mean**	Median	Min	Max	Stdev	n	
Unit: ppm (mg/kg) dw							
Silver (AG)	**1.010**	0.690	0.031	6.484	1.198	58	**0.74**
Aluminum (AL)	**506**	424	29	1668	377	58	**1.27**
Arsenic (As)	**11.62**	10.50	5.90	30.80	4.32	58	**1.17**
Cadmium (CD)	**4.24**	3.17	0.43	15.56	2.89	58	**1.02**
Chromium (CR)	**3.10**	2.94	1.07	11.76	1.75	58	**0.67**
Copper (CU)	**9.10**	8.78	3.64	15.78	2.81	58	**0.92**
Iron (FE)	**679**	588	55	2305	492	58	**1.12**
Mercury (HG)	**0.137**	0.112	0.034	0.501	0.086	58	**0.80**
Manganese (MN)	**23.92**	17.09	4.36	145.56	23.05	58	**0.88**
Nickel (NI)	**2.69**	2.36	0.25	8.65	1.78	58	**1.46**
Lead (PB)	**1.430**	1.012	0.140	7.278	1.309	58	**0.73**
Selenium (SE)	**4.30**	3.85	2.13	10.64	1.67	58	**1.23**
Tin (SN)	**0.274**	0.164	0.000	1.659	0.387	58	**1.02**
Zinc (ZN)	**168.4**	166.6	70.1	308.7	52.5	58	**0.49**
Monobutyltin MBT)	**1.95**	0.00	0.00	38.75	5.65	58	**0.61**
Dibutyltin DBT)	**9.89**	3.11	0.00	80.23	18.38	58	**0.34**
Tributyltin (TBT)	**24.84**	9.50	0.00	188.56	37.18	58	**0.20**
Tetrabutyltin (TetBT)	**0.00**	0.00	0.00	0.00	0.00	58	**NA**
Total Butyltins (Sum BT)	**36.68**	14.62	0.00	277.69	57.76	58	**0.26**

Appendix 10
Marine Discharge Glossary

Marine Discharge Glossary*

adapted from ADEC website:

http://www.state.ak.us/dec/press/cruise/crugloss.htm

Bilge Water: Water that collects in the lowest inner part of a ship's hull. Bilge water is frequently contaminated with oil and other lubricants from the engine room. Under various national and international standards, discharged bilge water must not exceed a certain maximum oil concentration (for example, 15 parts per million).

Black Water: Water contaminated with human waste, collected from shipboard toilets. Under various national and international standards, black water must be treated before being discharged from a vessel.

Discharge: In this context, any solid or liquid material that emanates from a vessel to a body of water, including anything spilled, leaked, poured, pumped, emitted or dumped from the vessel.

Geometric mean: The *n*th root of the product of a series of n numbers computed by taking the logarithm of each number, computing the arithmetic mean of the logarithms, and raising the base used to take the logarithms to the arithmetic mean.

Gray Water: Used water from showers, sinks or basins, including used kitchen water.

Marine sanitation device: Equipment that is installed on board a vessel, and that is designed to receive, retain, or discharge sewage; and any process to treat sewage on board a vessel.

MARPOL: Name given to the standards and requirements adopted by the International Convention for the Prevention of Pollution from Ships governing the discharge of oil and other hazardous substances, sewage, and garbage.

Sewage: Human body wastes and the wastes from toilets and other receptacles intended to receive or retain human body wastes.

* *These are general definitions and are not intended to conform to any specific State, federal, or international requirement. They are provided as a general background to the issues being discussed in this paper.*